COMMISSION
NINETEENTH REGULAR SESSION

Da Nang, Viet Nam
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Reference Document for Bigeye, Yellowfin and Skipjack tuna for the Review of CMM 2021-01 and Development of Harvest Strategies under CMM 2014-06

WCPFC19-2022-09
11 November 2022

Secretariat

A. INTRODUCTION

1. The purpose of this paper is to provide a quick reference guide to the recommendations of the latest Scientific Committee (SC) and Technical and Compliance Committee (TCC) of relevance to the discussions in support to the review CMM for tropical tunas (CMM 2021-01) and the development of the WCPFC harvest strategy framework. This paper includes SC18 recommendations on the development of the harvest strategy framework for key tuna species, mixed fishery MSE framework, and SC18 and TCC18 recommendations on the review of CMM 2021-01. The results of the latest stock assessments for bigeye and yellowfin from SC16 and skipjack from SC18 are in **Attachments 1 - 3**.

B. SCIENTIFIC COMMITTEE RECOMMENDATIONS

B.1 Development of the harvest strategy framework for skipjack tuna

1) Skipjack tuna TRP analyses *(Paragraph 53 - 58, SC18 Outcomes Document)*

2. Noting the Commission is scheduled to adopt a target reference point (TRP) for skipjack tuna in 2022, and the request from WCPFC18 for SC18 to review any additional information on TRPs for skipjack tuna, SC18 reviewed SC18-MI-WP-09 (*Further updates to WCPO skipjack tuna projected stock status to inform consideration of an updated target reference point*).

3. SC18 noted that the updated stock assessment for skipjack tuna (accepted by SC18) indicates that the median value of $SB_{recent}/SB_{F=0}$ relative to the spawning potential depletion in 2012 was 0.85. Based on preliminary deterministic projections, the ratio of $SB_{recent}/SB_{F=0}$ to the level of projected equilibrium spawning potential depletion reached under 2012 fishing conditions was 1.00. $SB_{recent}/SB_{F=0}$ relative to the average of these two values, as maybe used to recalibrate a TRP, was 0.93. Alternatively, the ratio of $SB_{recent}/SB_{F=0}$ to the interim TRP of $50\%SB_{F=0}$ is 1.02.

4. Several CCMs noted that one of the challenges with the specification of absolute depletion-based TRPs is their possible susceptibility to changes in the perception of stock status when successive stock assessments predict different stock trajectories or levels. To counter this, it was recommended the

Commission adopt TRPs specified in terms of a reference year, or a set of years.

5. SC18 was informed that the interim TRP for skipjack tuna is 50% of the spawning biomass in the absence of fishing ($SB_{F=0}$) as set out in CMM 2015-06, and while the TRP is still under review, no agreement had been reached at WCPFC18.

6. SC18 requested the Scientific Service Provider update SC18-MI-WP-09 (Table 2) to include evaluations based on the 2022 skipjack assessment (the Scientific Services Provider noted that this will need to wait until updates to the current software are completed). This update should be performed using the same settings as SC18-MI-WP-09 and include the projected outcomes from a set of candidate TRP options ranging between 40% to 60% depletion ratios and should continue to assess the change in purse seine effort from 2012 levels for the different candidate TRPs, the change in depletion relative to 2018-2021 average levels, as well as the projected impacts on equilibrium yields and the risk of breaching the LRP.

7. SC18 recommended that this update be provided to WFCPF19, and that the Commission take appropriate management action to ensure that the biomass depletion level fluctuates around the TRP (e.g., through the adoption of a harvest control rule).

2) Skipjack operating models *(Paragraphs 59 -65, SC18 Outcomes Document)*

8. Noting the Commission is scheduled to adopt a management procedure (MP) for skipjack tuna in 2022, and the request from WCPFC18 for SC18 to review and recommend an agreed grid of operating models (OMs) that reflect important sources of uncertainty and plausible states of nature for WCPO skipjack, SC18 reviewed SC18-MI-WP-01 (*Operating models for skipjack tuna in the WCPO*).

9. SC18 noted the settings and configurations of the models that comprise the reference set of OMs for skipjack tuna are working well. While there were some differences, the range of uncertainty in the trajectories of spawning potential depletion estimated by the reference set spanned the results of the 2022 stock assessment, especially in recent years. Noting that stock assessments focus on historical uncertainty while OMs focus on future uncertainty, updating the reference set of OMs to be based on the 2022 assessment was unlikely to result in any changes in the relative performance of candidate MPs.

10. SC18 also noted that the OM grid should not require updating each time a new assessment is accepted unless new evidence is provided that indicates that population dynamics or key uncertainties are substantially outside of the bounds of that encompassed by the OM sets. Such an instance would be covered under exceptional circumstances.

11. SC18 also noted that further expansion of the axes of uncertainty at this time, as suggested by some CCMs, would unlikely change the relative performance of candidate MPs.

12. SC18 agreed to accept the reference set of 96 OMs as currently specified in SC18-MI-WP-01, noting the broad range of uncertainty encompassed by the grid axes, and recommended this reference set be adopted by WCPFC19.

13. SC18 agreed, and recommended to WCPFC19, to provisionally adopt the robustness set of OMs as listed in Table 1 of SC18-MI-WP-01, noting that SC18 also discussed expanding this set of models to include additional uncertainties. These included models that could account for effort-creep in the Japanese pole-and-line fisheries, likely changes on skipjack productivity due to the impacts of climate change, and a lower productivity (lower recruitment) ‘stress test’. This further work is an integral part of the MSE and will be presented to SC19 and where possible key elements will be presented to WCPFC19.

14. Noting that the Commission is scheduled to adopt a monitoring strategy for skipjack tuna in 2023, SC18 noted that further discussion will be undertaken at SC19.

3) Skipjack management procedure (MP) and evaluations *(Paragraphs 66 - 73, SC18 Outcomes Document)*

15. Noting the Commission is scheduled to adopt an MP for skipjack tuna in 2022, and the request from WCPFC18 for SC18 to review further progress on developing and testing the performance of candidate MPs for WCPO skipjack, SC18 reviewed the analyses included in SC18-MI-WP-02 (*Evaluations of candidate management procedures for skipjack tuna in the WCPO).*

16. SC18 thanked the Scientific Service Provider for the latest information on the testing of candidate MPs for skipjack tuna and noted that the continued development of the PIMPLE software package had been particularly useful in evaluating candidate harvest control rules (HCRs). However, noting the similar performance of many candidate HCRs, and the limited ability of the current suite of performance indicators to distinguish between them, SC18 expressed support for the development of an overall performance measure that allows for alternative weighting of indicators. Inclusion in PIMPLE of information on the values of the threshold points in each HCR was also supported. It was also suggested that the "Compare performance" button should go to the box plots by default (rather than the bar charts) to prioritize the display of uncertainty (a key aspect of comparing performance).

17. One CCM also suggested that the results of robustness testing be included within PIMPLE and welcomed discussion and potential inclusion of additional models within the robustness set.

18. Several CCMs supported running the MP every three years, as it replicates, more or less, the timescale of the current assessment cycle for WCPFC tuna stocks. However, the additional burden this would place on the Scientific Services Provider, and also on WCPFC members providing supporting analyses, was noted.

19. One CCM recommended that WCPFC19 note that the current candidate MPs are evaluated against the 2012 depletion ratio calculated from the current OM grid that is based on 2019 assessment, which is about 42%$SB_{F=0}$, and cannot be automatically modified to a different target level when future assessments show a different level of depletion for 2012. SC18 noted the earlier explanation of the Scientific Services Provider on how performance relative to the TRP can be used when evaluating performance. This CCM also expressed their concern about having effort control for purse-seine fisheries while other fisheries are controlled by catch.

20. SC18 noted that additional agreed performance indicators will need to be reported on through the monitoring strategy after an MP is adopted. In this regard one CCM also supported the future development of a performance indictor for measuring the impact on small-scale fisheries.

21. SC18 noted that all candidate HCRs should allow for minimal fishing mortality below the LRP as part of their initial design as completely closing the fishery would result in information loss, preventing ongoing assessment of the status of the stock. SC18 further noted that, from the results of the evaluations, the likelihood of the stock falling below the LRP was extremely small.

22. SC18 agreed that the framework necessary for evaluating candidate MPs for skipjack tuna is now fully established and ready for consideration by the Science-Management Dialogue and WCPFC19 for the adoption of an MP on schedule in 2022. However, SC18 did not see that its role was to recommend any particular MP but to furnish the Commission with the tools to do so, and noted the use of the PIMPLE tool

for this purpose. Nevertheless, SC18 noted that on biological grounds none of the candidate MPs should be recommended for rejection on the basis of LRP risk. SC18 also noted that there will be further discussion concerning MPs for skipjack at the upcoming Science-Management Dialogue.

4) **Skipjack MP implementation** *(Paragraphs 74 - 79, SC18 Outcomes Document)*

23. Noting the Commission is scheduled to adopt an MP for skipjack tuna in 2022, SC18 reviewed an example of how a skipjack MP could be implemented to illustrate the function, performance, and implications of a hypothetical MP as outlined in SC18-MI-WP-03 (*WCPO skipjack management procedure: dry run*).

24. SC18 thanked the Scientific Service Provider for the 'dry run' analysis and agreed that it was very helpful in illustrating the function, performance, and implications of a hypothetical MP.

25. SC18 noted that based on the analyses presented, there was sufficient data in the monitoring strategy to generate the inputs to run the estimation model and to provide a reliable estimate of stock status. As the estimation model is part of the MP, this was seen as a step forward in the development of an MP for skipjack tuna which should make it easier to adopt an MP by the end of 2022.

26. SC18 also noted that the estimation model is based on fixed parameter settings and that only the stock status in the terminal year of the estimation model is used in the MP. It is the combined output of the estimation model and the harvest control rule that determines the performance of an MP.

27. Several CCMs supported undertaking the full stock assessment and running the MP in different years in order to separate the processes of running the MP to set new management levels, and running the full stock assessment to monitor the performance of the MP.

28. Noting that a monitoring strategy for skipjack tuna is scheduled to be adopted by the Commission in 2023, SC18 supported further discussion on this issue at SC19, including mechanisms for the collection of data for the range of agreed performance indicators not generated by the MSE framework (such as economic PIs). Several CCMs also noted that exceptional circumstances should be defined in relatively simple and broad terms and avoid being overly prescriptive as flexibility is needed to adapt to future unpredictable situations. It was noted that draft exceptional circumstances text submitted to the ODF under Topic 17 (SC18-MI-IP-03) generally conformed with this approach.

B.2 Mixed fishery MSE framework

1) **Bigeye and yellowfin tuna TRP analyses** *(Paragraphs 92, SC18 Outcomes Document)*

29. Noting the Commission is scheduled to adopt a TRP for both bigeye tuna and yellowfin tuna in 2022, that the results of the analyses on candidate TRPs for bigeye and yellowfin had been reviewed by SC17 and presented to WCPFC18, and noting that no further analyses had been undertaken since, SC18 was unable to provide any further advice or recommendations to the Commission on this issue and reiterates the advice provided by SC17, as follows (subparagraphs i-v below):

(i) SC17 noted that these analyses (see SC17-MI-WP-01) reflected the original request made by SC16, and the additional request by the Commission for additional information. SC17 also noted the usefulness of these updates as they facilitate an improved understanding of multispecies implications of alternative harvest levels.

(ii) SC17 noted that impacts on skipjack tuna depletion associated with relative changes to fishing levels to achieve a candidate bigeye tuna TRP are contingent on the proportion of fishing scalars related to purse seine fishing that target skipjack tuna. The relative change in fishing scalars to achieve candidate TRPs assume equal proportionality in purse seine and longline fishing scalars, provided for comparative purposes from the SC16 request.

(iii) SC17 noted that the analyses will greatly aid in considering candidate TRPs for bigeye and yellowfin tuna.

(iv) SC17 also noted that the risks of breaching the LRPs outlined in the paper are dependent on the treatment of uncertainty in any assessment and may underestimate uncertainty.

(v) SC17 recommended forwarding this working paper to the Commission for its deliberations on target reference points for bigeye and yellowfin tuna and that the results be taken into account at the next Tropical Tuna Workshop.

2) **Mixed fishery update and performance indicators** *(Paragraphs 93 - 98, SC18 Outcomes Document)*

30. Noting the work reviewed by SC17 in developing a multi-species modelling framework for including mixed fishery interactions when developing and testing harvest strategies for the four main WCPO tuna stocks, SC18 reviewed an update on the development of this framework outlined in SC18-MI-WP-06 (*Mixed fishery harvest strategy update*) and SC18-MI-WP-07 (*Mixed-fishery harvest strategy performance indicators*).

31. SC18 thanked the Scientific Service Provider for the progress in developing the mixed fishery harvest strategies and noted the encouraging results in including South Pacific albacore in the multi-species modelling framework. However, SC18 also noted that considerable work remains to be completed, such as building a full suite of OMs for bigeye and yellowfin tuna and considering candidate MPs for the tropical longline fisheries.

32. SC18 noted that most of the performance indictors used in the working paper were useful and easy to understand, but also noted that the indicators may need to be separated for fisheries, and the set of performance indicators could be further developed (such as an indicator related to stability and impacts on SIDS). SC18 also noted that the question about what indicators are necessary is generally a management or policy decision.

33. Several CCMs, in noting that the analysis outlined in SC18-MI-WP-07 indicated a larger impact by the purse-seine fleet on bigeye tuna than the impact of the tropical longline fleet, explained that they had not yet agreed on the mixed fisheries MSE framework outlined in this paper (e.g., the order in which the individual MPs are implemented). They suggested, for instance, that a stock status-based approach could be considered while another CCM suggested a stock productivity-based approach may also be considered. However, the difficulty in implementing such approaches was acknowledged.

34. Several CCMs noted they would not be able to support any proposed MP outcomes unless those outcomes are designed to ensure that there is no disproportionate burden transfer. They also noted that it will not usually be possible to achieve all the TRPs at the same time and that there will need to be trade-offs.

35. SC18 supported continuing the work on the development of the mixed fishery MSE framework and recommended that both the Science-Management Dialogue and WCPFC19 take note of the progress to date and provide feedback.

B.3 Review of CMM 2021-01

1) FAD Management Options IWG issues *(Paragraph 125 - 127, SC18 Outcomes Document)*

36. SC18 noted that in the ODF there was support / no objection to the proposed IATTC definition of biodegradable and categories of biodegradable FADs (paragraph 10, SC18-EP-IP-13). Responding to the Commission's tasks under the CMM 2021-01, SC18 supported the definition of "biodegradable" and several preliminary categories of biodegradable FADs to be considered for its gradual implementation as stated in paragraph 10, SC18-EP-IP-13 and listed below:

- "Non-synthetic materials[1] and/or bio-based alternatives that are consistent with international standards[2] for materials that are biodegradable in marine environments. The components resulting from the degradation of these materials should not be damaging to the marine and coastal ecosystems or include heavy metals or plastics in their composition."
- The different categories to be considered in this gradual implementation process are (These definitions do not apply to electronic buoys attached to FADs to track them):
- Category I. The FAD is made of 100% biodegradable materials.
- Category II. The FAD is made of 100% biodegradable materials except for plastic-based flotation components (e.g., plastic buoys, foam, purse-seine corks).
- Category III. The subsurface part of the FAD is made of 100% biodegradable materials, whereas the surface part and any flotation components contain nonbiodegradable materials (e.g., synthetic raffia, metallic frame, plastic floats, nylon ropes).
- Category IV. The subsurface part of the FAD contains non-biodegradable materials, whereas the surface part is made of 100% biodegradable materials, except for, possibly, flotation components.
- Category V. The surface and subsurface parts of the FAD contain nonbiodegradable materials.

37. SC18 noted that these categories are preliminary and will be further examined by the FADMO-IWG, SC, TCC for Commission's consideration.

38. SC18 further recommended to the Commission that the FADMO-IWG continues its work on exploring a timeline for the stepwise introduction of biodegradable FADs, potential gaps/needs and any other relevant information for Commission's consideration. SC18 noted that the FADMO-IWG may seek advice from SC and TCC.

2) Other commercial fisheries for bigeye, yellowfin and skipjack tuna *(Paragraph 4, SC18 Outcomes Document)*

39. SC18 noted the information provided by Indonesia related to options for a baseline of the "large-fish" handline fishery fishing in Indonesia's EEZ. SC18 observed the decision on this fishery's baseline is a policy decision, and that it did not believe it appropriate to provide any recommendations on a baseline, but recommended the Commission consider the information provided in the relevant SC18 papers and the comments in the SC18 Online Discussion Forum (ODF)[3] on the topic in its decisions making.

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[1] For example, plant-based materials such as cotton, jute, manila hemp (abaca), bamboo, or animal-based such as leather, wool, lard.

[2] International standards such as ASTM D6691, D7881, TUV Austria, European or any such standards approved by the WCPFC CCMs.

[3] https://forum.wcpfc.int/c/sc-18/23

C. TECHNICAL AND COMPLIANCE COMMITTEE RECOMMENDATIONS

C.1 Advice on the baseline period or limit for the Indonesia Large Fish Handline Fishery *(Paragraph 133 and 134, TCC18 draft Summary Report)*

40. TCC18 noted the information provided by Indonesia in TCC18-2022-16 and observed that the decision on the baseline period for the Indonesian large fish handline fishery is a decision for the Commission.

41. TCC18 invited Indonesia to submit a comprehensive paper to WCPFC19 to provide any additional information on their fisheries and the trends, particularly in relation to the large fish handline fishery.

C.2 Preliminary review of available information on biodegradeable FADs *(Paragraph 246 - 248, TCC18 draft Summary Report)*

42. TCC18 supported the SC18 recommendations related to biodegradeable FADs as detailed in supporting paper **TCC18-2022-25**.

43. TCC18 recommended that WCPFC19 endorse the interpretation of paragraph 17 of CMM 2021-01 as presented by the FAD Management Options IWG Chair in the TCC18 ODF Summary Report (TCC18-2022-05): "paragraph 17 prohibits deploying FADs with mesh net after 1 January 2024."

44. TCC18 noted the need to revisit the ROP minimum data fields related to FADs, particularly monitoring of non-entangling and biodegradable FADs implementation in the future, to improve data quality in this area. TCC18 recommended that if the IWG-ROP, once it is reactivated that it, be tasked to undertake this work.

Attachment 1

The Commission for the Conservation and Management of
Highly Migratory Fish Stocks in the Western and Central Pacific Ocean

Scientific Committee
Sixteenth Regular Session

Electronic Meeting
12 – 19 August 2020

WCPO BIGEYE TUNA STOCK ASSESSMENT

(Paragraphs 81– 98, SC16 Summary Report)

Provision of scientific information

a. Stock status and trends

1. The median values of relative recent (2015-2018) spawning biomass depletion ($SB_{recent}/SB_{F=0}$) and relative recent (2014-2017) fishing mortality (F_{recent}/F_{MSY}) over the uncertainty grid of 24 models (Table BET-1) were used to define stock status. The values of the upper 90th and lower 10th percentiles of the empirical distributions of relative spawning biomass and relative fishing mortality from the uncertainty grid were used to characterize the probable range of stock status.

2. A description of the updated structural sensitivity grid used to characterize uncertainty in the assessment is illustrated in Table BET-1. The spatial structure used in the 2020 stock assessment is shown in Figure BET-1. Time series of total annual catch by fishing gear over the full assessment period is shown in Figure BET-2. The time series of total annual catch by fishing gear and assessment region is shown in Figure BET-3. Estimated annual average recruitment, spawning potential and total biomass by model region is shown in Figure BET-4. Estimated trends in spawning potential by region for the diagnostic case is shown in Figure BET-5, and juvenile and adult fishing mortality rates from the diagnostic model is shown in Figure BET-6. Estimates of the reduction in spawning potential due to fishing by region is shown in Figure BET-7. Time-dynamic percentiles of depletion ($SB_t/SB_{t,F=0}$) for the 24 models are shown in Figure BET-8. A Majuro and Kobe plot summarising the results for each of the 24 models in the structural uncertainty grid are shown in Figures BET 9 and 10, respectively. Projections are illustrated in Figures BET-11 and BET-12. Table BET-2 provides a summary of reference points over the 24 models in the structural uncertainty grid.

3. A number of investigative models were run with growth, such as: 1) *Oto-Only*, a growth curve that was a fixed Richards growth curve based on high-readability otoliths, 2) *Tag-Int*: a growth curve that was a fixed Richards growth curve based on the same high-readability otolith data-set in addition to bigeye tuna tag-recapture data, and 3) *Est-Richards*: A conditional age-length data-set was constructed from the combined daily and annual otolith dataset. The *Oto-Only* growth model predicted very high levels of biomass and corresponding low level of depletion. The *Est Richards* growth model showed sensitivity to the initial values given for the estimated growth parameters. The implausible results from the *Oto-Only* growth and differing results from the *Est-Richards* indicate questions still remain regarding bigeye tuna growth.

4. SC16 requested the bigeye tuna assessment to try and fit the data for those small bigeye tuna as they are increasingly caught by domestic fisheries in region 7, but the current diagnostic model does not fit

those fish that well because the L1 parameter is larger than most of those fish. SPC could consider additional developments to Multifan-CL to model greater variability in size around the growth curve at small ages.

5. The most influential grid axis is the size-frequency data-weighting axis and further research is required to develop model diagnostics and objective criteria for model inclusion.

Table BET-1. Description of the updated structural sensitivity grid used to characterize uncertainty in the assessment. The starred levels denote those assumed in the model diagnostic case.

Axis	Value 1	Value 2	Value 3	Value 4
Steepness	0.65	0.8 *	0.95	
Natural mortality	Diagnostic* (0.112)	M-hi (0.146)		
Size frequency weighting	20*	60	200	500

Table BET-2. Summary of reference points over the 24 models in the structural uncertainty grid. Note that "recent" is the average over the period 2015-2018 for SB and 2014-2017 for fishing mortality, while "latest" is 2018. The values of the upper 90th and lower 10th percentiles of the empirical distributions are also shown. F_{mult} is the multiplier of recent (2014-2017) fishing mortality required to attain MSY.

	Mean	Median	Minimum	10^{th} percentile	90^{th} percentile	Maximum
C_{latest}	159,738	159,288	157,297	157,722	162,033	162,271
$Y_{Frecent}$	136,568	134,940	117,800	124,668	149,424	161,520
f_{mult}	1.45	1.38	0.83	0.98	2.03	2.33
F_{MSY}	0.05	0.05	0.04	0.04	0.07	0.07
MSY	146,715	140,720	117,920	125,628	179,164	187,520
F_{recent}/F_{MSY}	0.74	0.72	0.43	0.49	1.02	1.21
$SB_{F=0}$	1,395,173	1,353,367	903,708	982,103	1,780,138	1,908,636
SB_{MSY}	320,162	321,550	192,500	219,810	443,730	482,700
$SB_{MSY}/SB_{F=0}$	0.23	0.23	0.19	0.2	0.26	0.26
$SB_{latest}/SB_{F=0}$	0.38	0.38	0.23	0.3	0.47	0.51
SB_{latest}/SB_{MSY}	1.7	1.67	0.95	1.23	2.15	2.6
$SB_{recent}/SB_{F=0}$	0.4	0.41	0.21	0.27	0.52	0.55
SB_{recent}/SB_{MSY}	1.78	1.83	0.87	1.18	2.32	2.84

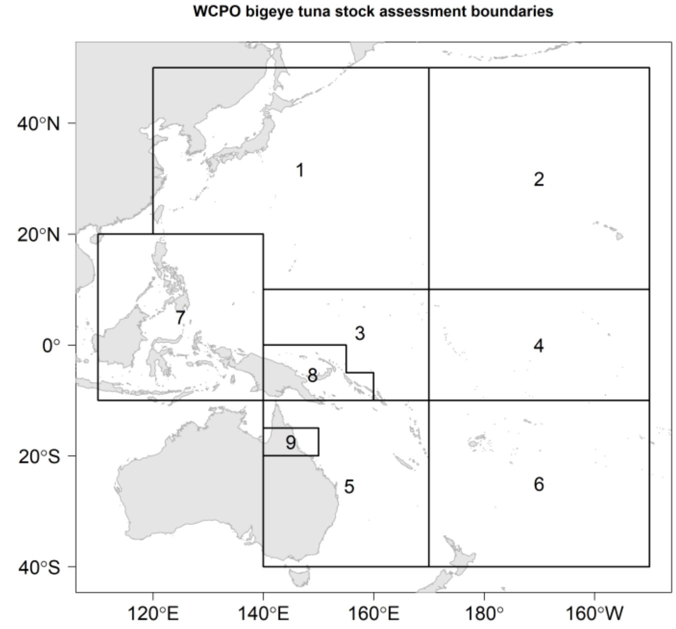


Figure BET-1. Spatial structure for the 2020 bigeye tuna stock assessment.

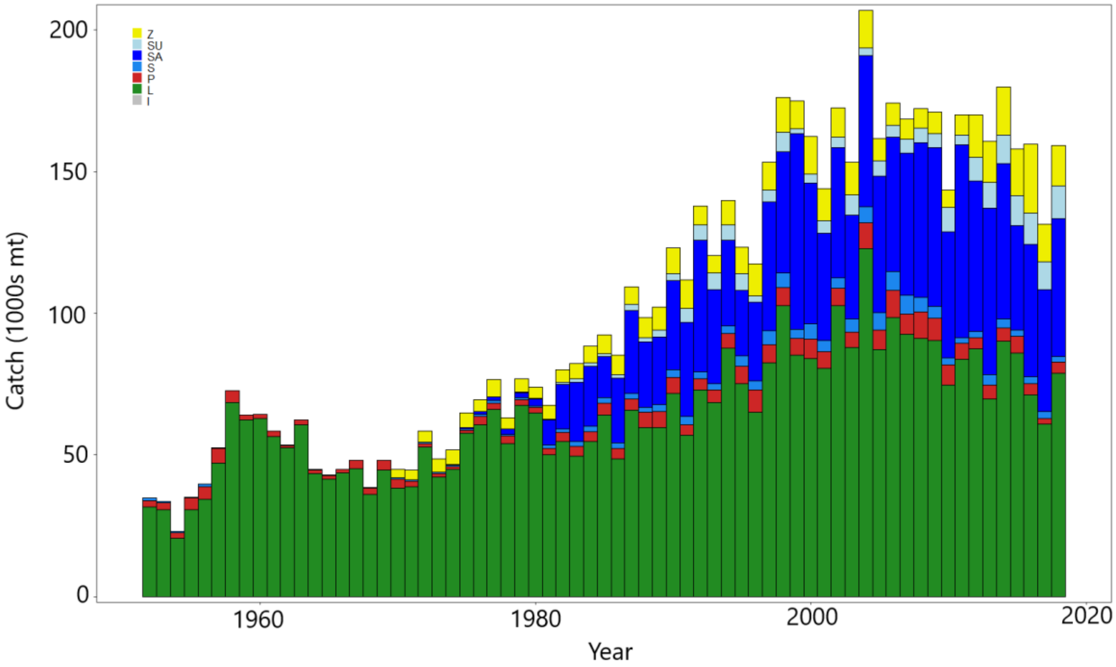


Figure BET-2. Time series of total annual catch (1000s mt) by fishing gear for the diagnostic model over the full assessment period. The different colors refer to longline (green), pole-and-line (red), purse seine (blue), purse seine associated (dark blue), purse seine unassociated (light blue), miscellaneous (yellow), and index (gray). Note that the catch by longline gear has been converted into catch-in-weight from catch-in-numbers and so may differ from the annual catch estimates presented in (Williams et al., 2020), however these catches enter the model as catch-in-numbers.

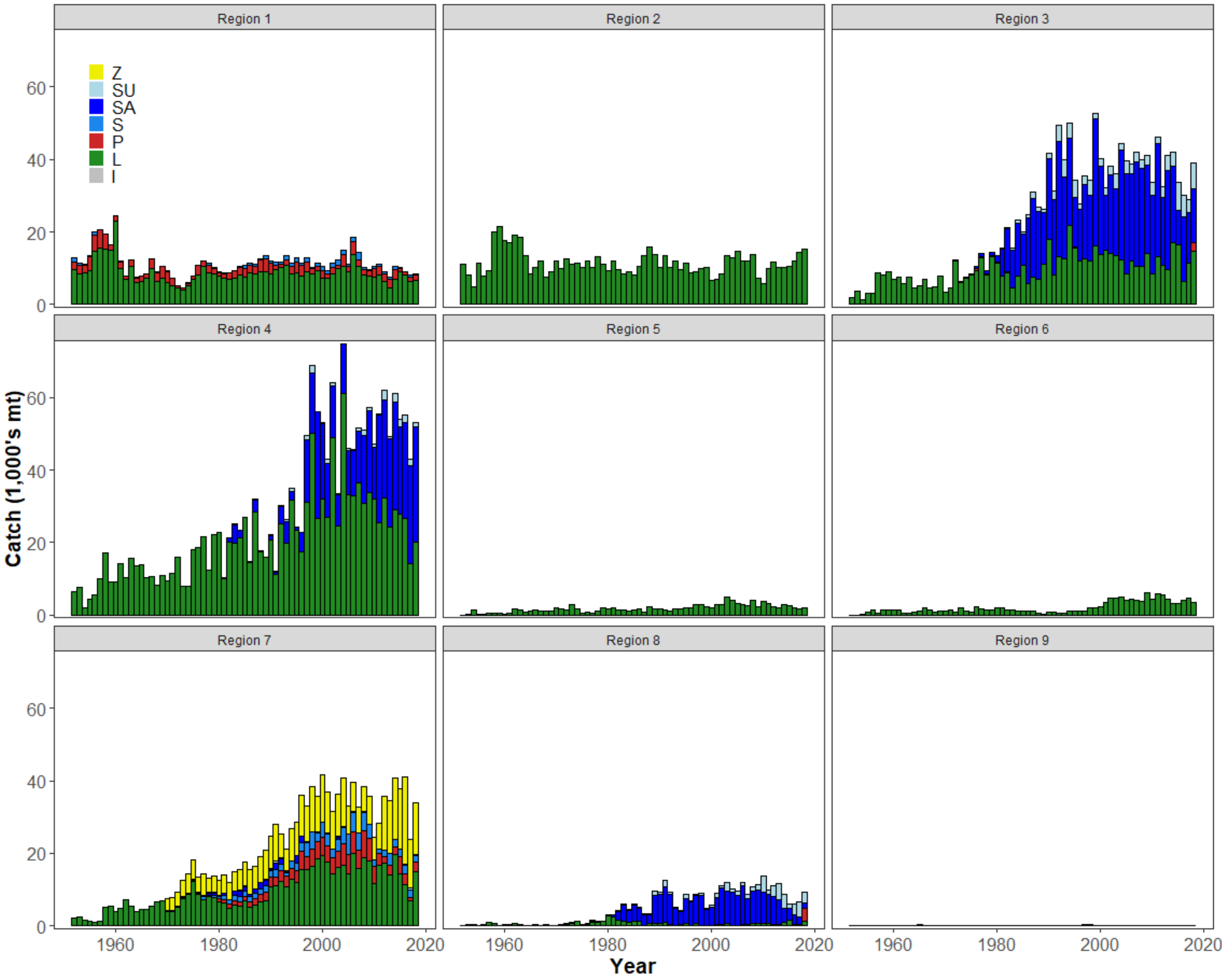
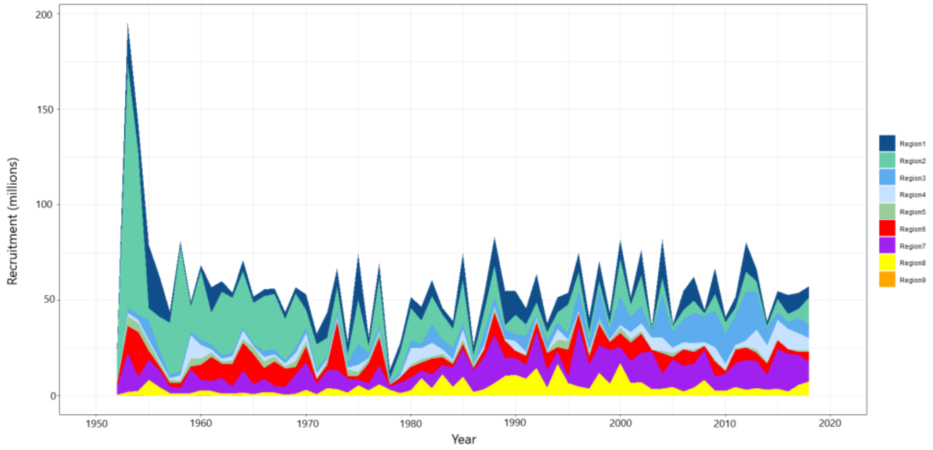
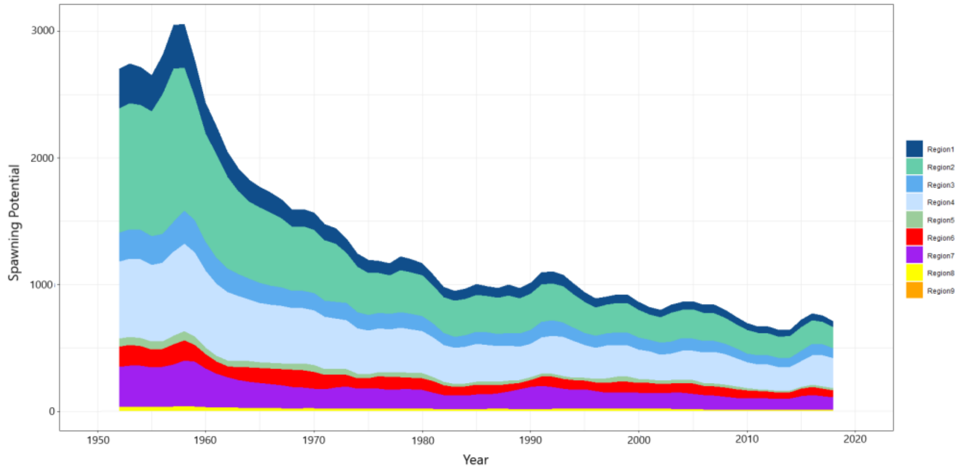


Figure BET-3. Time series of total annual catch (1000s mt) by fishing gear and assessment region for the diagnostic model over the full assessment period. The different colors refer to longline (green), pole-and-line (red), purse seine (blue), purse seine associated (dark blue), purse seine unassociated (light blue), miscellaneous (yellow), and index (gray).

(a) Recruitment



(b) Spawning Potential



(c) Total biomass

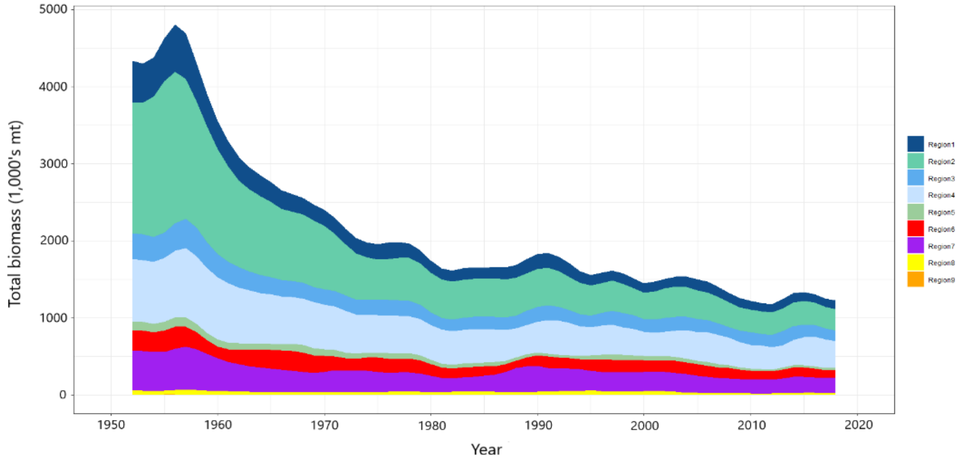


Figure BET-4. Estimated (a) annual average recruitment, (b) spawning potential and (c) total biomass by model region for the diagnostic model, showing the relative sizes among regions.

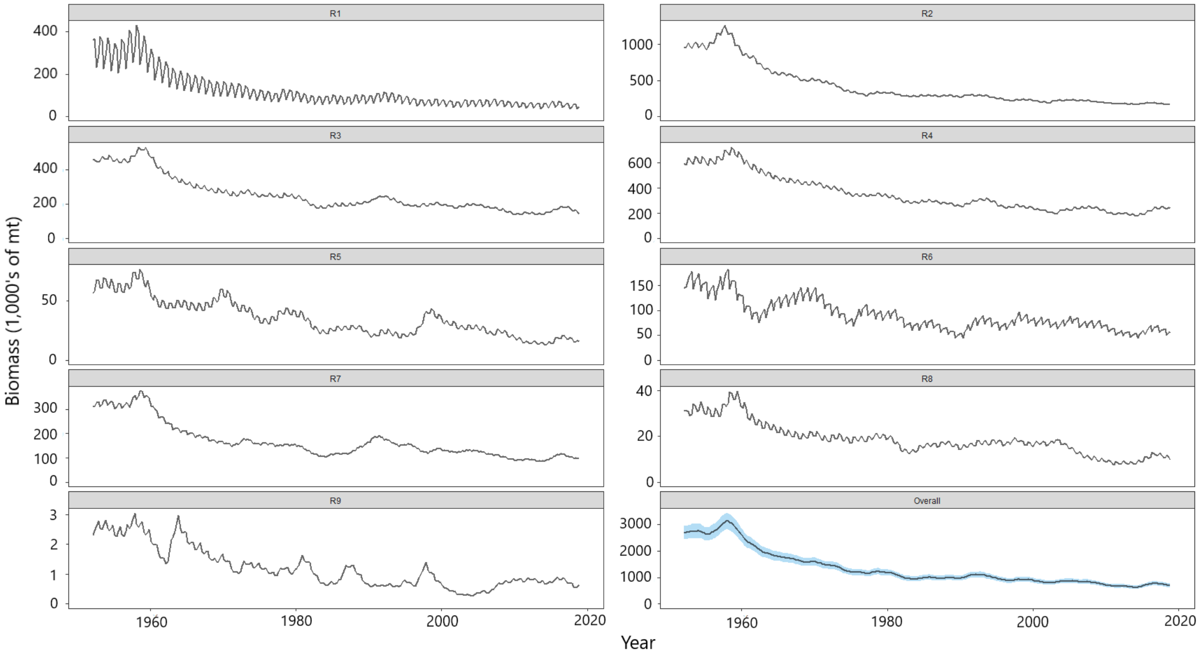


Figure BET-5. Estimated seasonal, temporal spawning potential by model region for the diagnostic model. The asymptotic 95% confidence interval as calculated using the delta-method is shown for the "Overall" region. Note that the scale of the y-axis is not constant across regions.

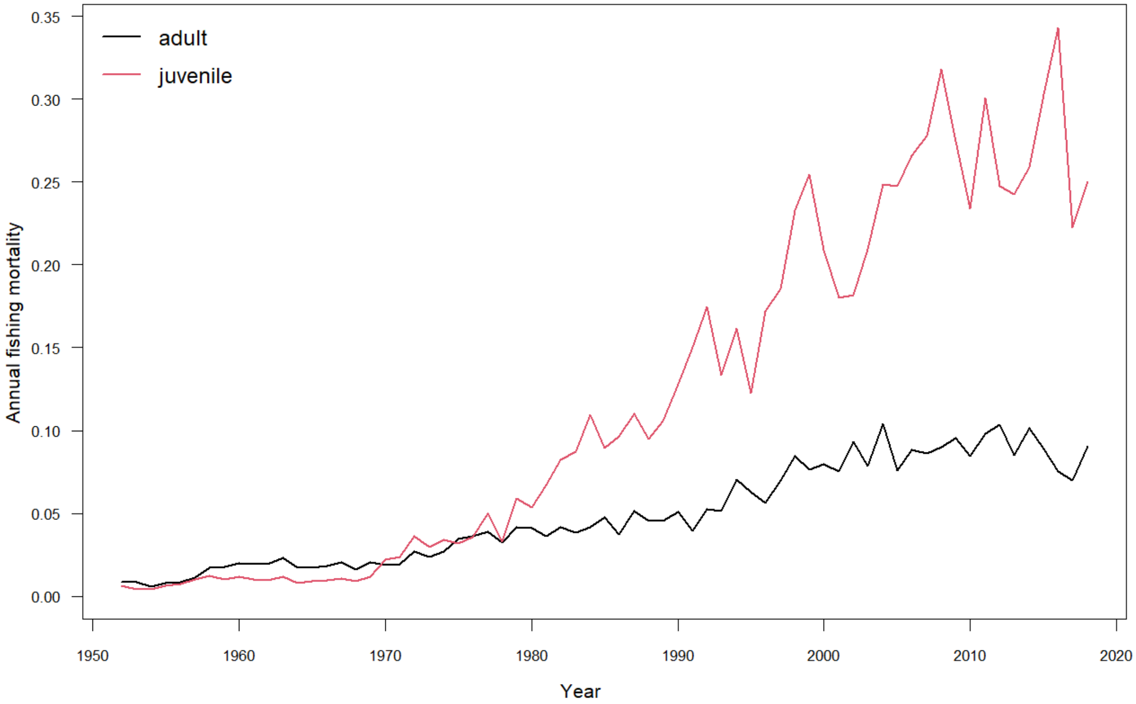


Figure BET-6. Estimated annual average juvenile and adult fishing mortality for the diagnostic model.

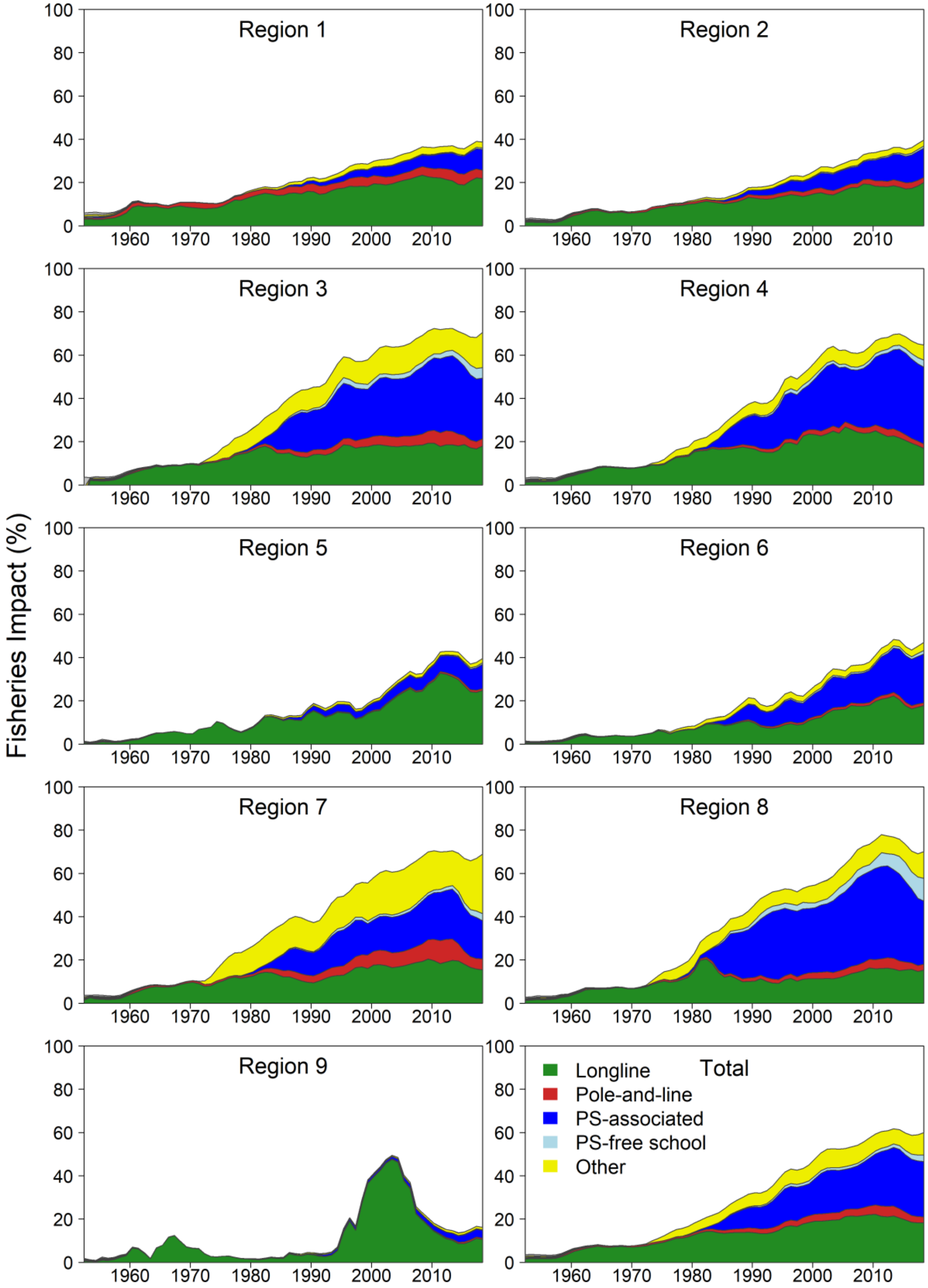


Figure BET-7. Estimates of reduction in spawning potential due to fishing (fishery impact = $(1\text{-}SB_t/SB_{t;F=0}) * 100\%$) by region, and over all regions (lower right panel), attributed to various fishery groups for the diagnostic model.

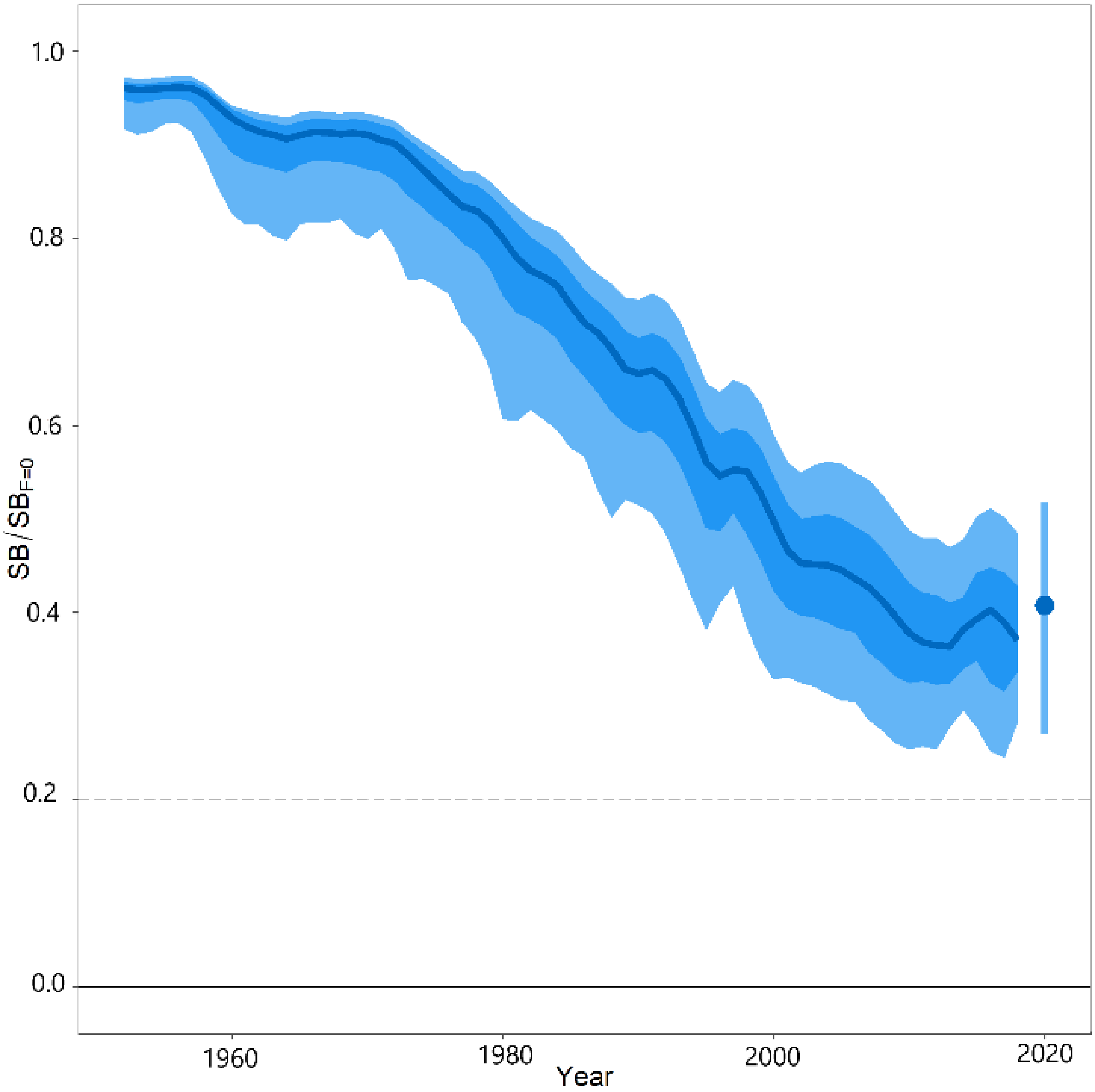


Figure BET-8. Time-dynamic percentiles of depletion ($SB_t/SB_{t;F=0}$) and median (dark line) across all 24 models in the structural uncertainty grid. The lighter band shows the 10th to 90th percentiles around the median, and the dark band shows the 50th percentile around the median. The median $SB_{recent}/SB_{F=0}$ and 80th percentile is shown on the right by the dot and line.

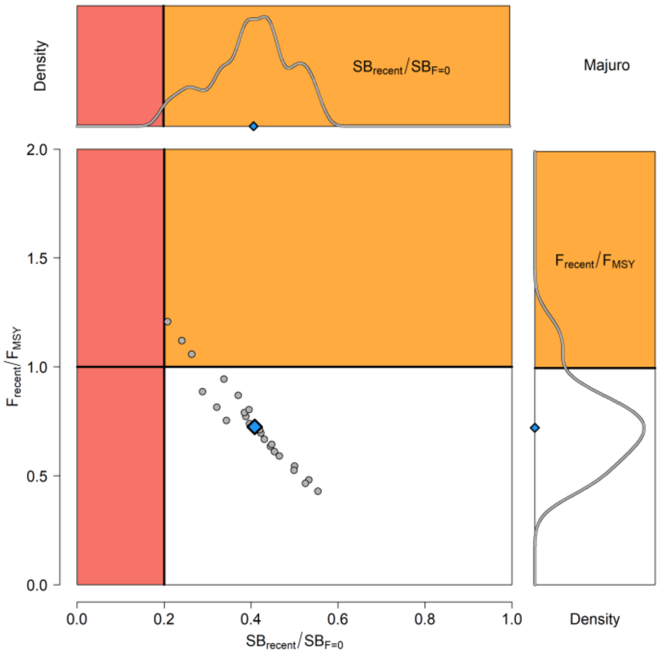


Figure BET-9. Majuro plot for the recent spawning potential (2015–2018) summarizing the results for each of the models in the structural uncertainty grid. The plots represent estimates of stock status in terms of spawning biomass depletion and fishing mortality, and marginal distributions of each are presented. The median is shown in blue.

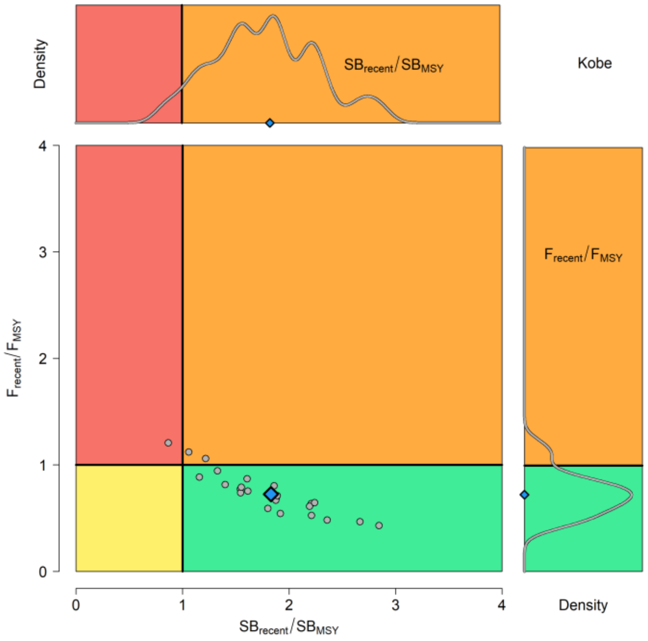


Figure BET-10. Kobe plot for the recent spawning potential (2015–2018) summarizing the results for each of the models in the structural uncertainty grid. The plots represent estimates of stock status in terms of spawning biomass depletion and fishing mortality. Marginal distributions of each are presented. The median is shown in blue.

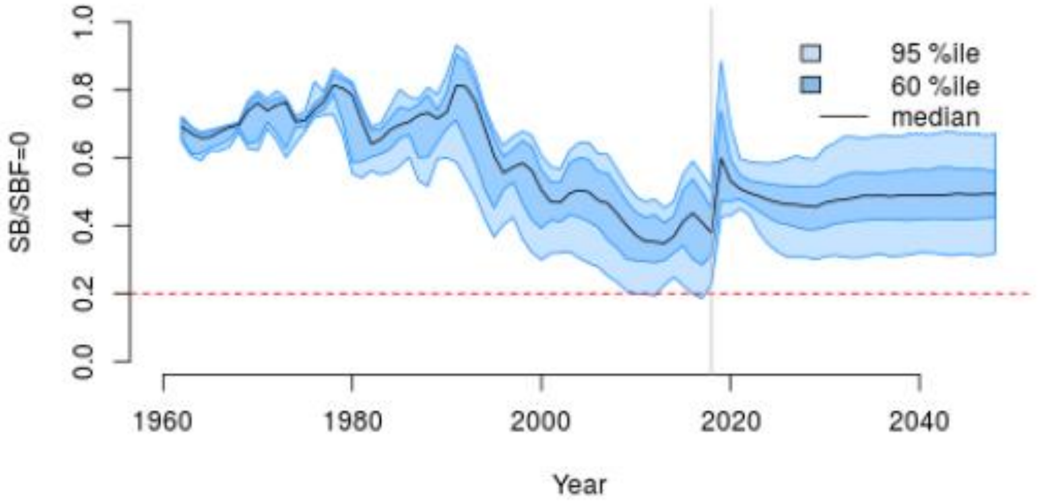


Figure BET-11. Time series of bigeye tuna spawning potential SB_t=$SB_{F=0}$, where $SB_{F=0}$ is the average SB from t-10 to t-1, relative to the current year t, from the uncertainty grid of assessment models for the period 2000 to 2018, and stochastic projection results for the period 2019 to 2048 assuming 2016-2018 average catches in LL and other fisheries and 2018 effort in PS fisheries continue. Vertical gray line at 2018 represents the last year of the assessment. During the projection period (2019-2048) levels of recruitment variability are assumed to match those over the short-term period (2008-2017). The red horizontal dashed line represents the agreed limit reference point.

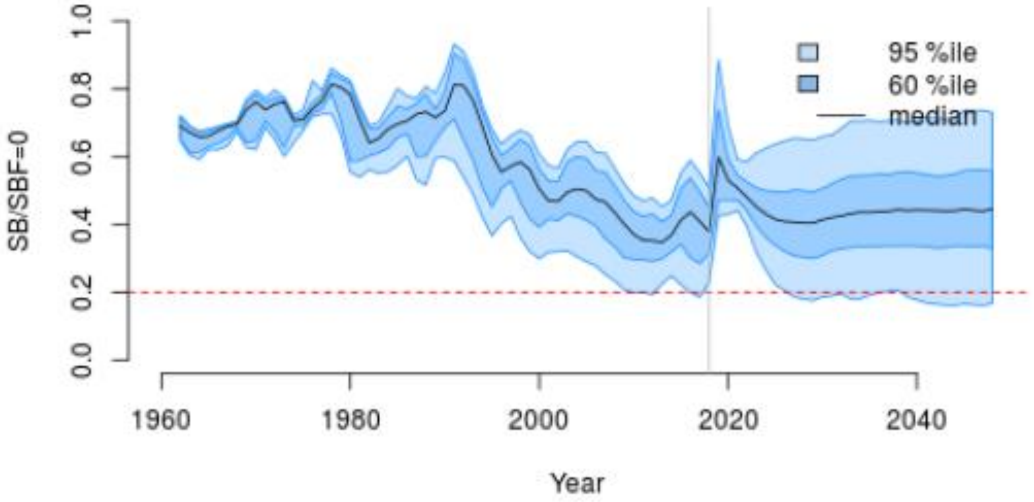


Figure BET-12. Time series of bigeye tuna spawning potential SB_t=$SB_{F=0}$, where $SB_{F=0}$ is the average SB from t-10 to t-1, relative to the current year t, from the uncertainty grid of assessment models for the period 2000 to 2018, and stochastic projection results for the period 2019 to 2048 assuming 2016-2018 average catches in LL and other fisheries and 2018 effort in PS fisheries continue. Vertical gray line at 2018 represents the last year of the assessment. During the projection period (2019-2048) levels of recruitment variability are assumed to match those over the long-term period (1962-2017). The red horizontal dashed line represents the agreed limit reference point.

6. SC16 noted that the results from the uncertainty grid adopted by SC16 show that the stock has been continuously declining for about 60 years since the late 1950s, except for the recent small increase from 2015 to 2016 with biomass declining thereafter.

7. SC16 also noted that the median value of relative recent (2015-2018) spawning biomass depletion ($SB_{2015-2018}/ SB_{F=0}$) was 0.41 with a 10th to 90th percentiles of 0.27 to 0.52.

8. SC16 further noted that there was 0% probability (0 out of 24 models) that the recent (2015-2018) spawning biomass had breached the adopted limit reference point (LRP).

9. SC16 noted that there has been a long-term increase in fishing mortality for both juvenile and adult bigeye tuna and while juvenile fishing mortality is higher than that of the adult fish, both adult and juvenile fishing mortality rates have stabilised somewhat since 2008 and have fluctuated without trend since that time.

10. SC16 noted that the median recent fishing mortality ($F_{2014-2017t}/F_{MSY}$) was 0.72 with a 10th to 90th percentile interval of 0.49 to 1.02.

11. SC16 noted that there was a roughly 12.5% probability (3 out of 24 models) that the recent (2014-2017) fishing mortality was above F_{MSY}.

12. SC16 noted the results of stochastic projections (Figures BET 11 and BET 12) from the 2020 assessment which indicated the potential stock consequences of fishing at “status quo” conditions (2016–2018 average longline and other fishery catch and 2018 purse seine effort levels) and short-term recruitment scenario using the uncertainty framework approach endorsed by SC. Projections indicate that median $SB_{\mathbf{2025}}/SB_{F=0}$ = 0.47; median $SB_{2035}/SB_{F=0}$ = 0.49 and median $SB_{2045}/SB_{F=0}$ = 0.49. The risk that $SB_{2048}/SB_{F=0}$ is less than the Limit Reference Point is 0%.

13. SC16 noted the results of stochastic projections from the long-term recruitment scenario using the uncertainty framework approach endorsed by SC. Projections indicate that median $SB_{2025}/SB_{F=0}$ = 0.42; median $SB_{2035}/SB_{F=0}$ = 0.44 and median $SB_{2045}/SB_{F=0}$ = 0.45. The risk that $SB_{2048}/SB_{F=0}$ is less than the Limit Reference Point is 5%.

b. Management advice and implications

14. SC16 noted that the preliminary estimate of total catch of WCPO bigeye tuna for 2019 was 135,680 mt, a 9% decrease from 2018 and an 8% decrease from the average 2014-2018. Longline catch in 2019 (68,371 mt) was a 0% decrease from 2018 and a 2% increase from the 2014-2018 average. Purse seine catch in 2019 (50,819 mt) was a 22% decrease from 2018 and a 17% decrease from the 2014-2018 average. Pole and line catch (1,400 mt) was a 66% decrease from 2018 and a 66% decrease from the average 2014-2018 catch. Catch by other gear totalled 15,090 mt and was a 33% increase from 2018 and 1% increase from the average catch in 2014-2018.

15. SC16 noted that the catch in the last year of the assessment (2018) was median 159,288 mt which was greater than the median MSY (140,720 mt).

16. Based on the uncertainty grid adopted by SC16, the WCPO bigeye tuna spawning biomass is above the biomass LRP and recent F is very likely below F_{MSY}. The stock is not overfished (100% probability $SB/SB_{F=0}>LRP$) and likely not experiencing overfishing (87.5% probability $F<F_{MSY}$).

17. SC16 noted that levels of fishing mortality and depletion differ among regions, and that fishery impact was higher in the tropical regions (Regions 3, 4, 7 and 8 in the stock assessment model), with particularly high fishing mortality on juvenile bigeye tuna in these regions. There is also evidence that the overall stock status is buffered with biomass kept at more elevated level overall by low exploitation in the temperate regions (1, 2, 6 and 9). SC16 therefore re-iterates that WCPFC17 could continue to consider measures to reduce fishing mortality from fisheries that take juveniles, with the goal to increase bigeye fishery yields and reduce any further impacts on the spawning biomass for this stock in the tropical regions.

18. Based on those results, SC16 recommends as a precautionary approach that the fishing mortality on bigeye tuna stock should not be increased from the level that maintains spawning biomass at 2012-2015 levels until the Commission can agree on an appropriate target reference point.

Attachment 2

The Commission for the Conservation and Management of
Highly Migratory Fish Stocks in the Western and Central Pacific Ocean

Scientific Committee
Sixteenth Regular Session

Electronic Meeting
12 - 19 August 2020

WCPO YELLOWFIN TUNA STOCK ASSESSMENT

(Paragraphs 122 – 138, SC16 Summary Report)

Provision of scientific information

a. Stock Status and trends

1. The median values of relative recent (2015-2018) spawning biomass depletion ($SB_{recent}/ SB_{F=0}$) and relative recent (2014-2017) fishing mortality (F_{recent}/F_{MSY}) over the uncertainty grid of 72 models (Table YFT-1) were used to define stock status. The values of the upper 90th and lower 10th percentiles of the empirical distributions of relative spawning biomass and relative fishing mortality from the uncertainty grid were used to characterize the probable range of stock status.

2. A description of the updated structural sensitivity grid used to characterize uncertainty in the assessment is illustrated in Table YFT-1. The spatial structure used in the 2020 stock assessment is shown in Figure YFT-1. Time series of total annual catch by fishing gear over the full assessment period is shown in Figure YFT-2. The time series of total annual catch by fishing gear and assessment region is shown in Figure YFT-3. Estimated annual average recruitment, spawning potential, and total biomass by model region is shown in Figure YFT-4. Estimated trends in spawning biomass depletion for the 72 models in the structural uncertainty grid is shown in Figure YFT-5, and juvenile and adult fishing mortality rates from the diagnostic model is shown in Figure YFT-6. Estimates of the reduction in spawning potential due to fishing by region are shown in Figure YFT-7. Time-dynamic percentiles of depletion ($SB_t/SB_{t,F=0}$) for the 72 models are shown in Figure YFT-8. A Majuro and Kobe plot summarising the results for each of the 72 models in the structural uncertainty grid are shown in Figures YFT-9 and 10, respectively. Projections are illustrated in Figure YFT-11. Table YFT-2 provides a summary of reference points over the 72 models in the structural uncertainty grid.

3. The most influential axis of uncertainty with respect to estimated stock status was growth. The most pessimistic model estimates occurred with models that assumed growth estimated from the modal progression information in the size composition data. The most optimistic stock status estimates were obtained from models that used the growth curve estimated externally from otolith data. Models where growth was estimated by the conditional age-at-length data resulted in estimates that were in between the other two, but were more consistent with the otolith growth curve models. Further research is required to develop alternative growth estimates at the regional spatial scale and develop model diagnostics and objective criteria for model inclusion.

Table YFT-1. Description of the updated structural sensitivity grid used to characterize uncertainty in the assessment, where * denotes the level assumed in the diagnostic model. Equal weighting was given to all axis values.

Axis	Value 1	Value 2	Value 3	Value 4
Growth	Conditional Age-at-length*	Modal (Size Composition)	Otolith	
Steepness	0.65	0.8 *	0.95	
Size Scalar	20	60 *	200	500
Mixing Period	1 Quarter	2 Quarters *		

Table YFT-2. Summary of reference points over the 72 models in the structural uncertainty grid. Note that “recent” is the average over the period 2015-2018 for SB and 2014-2017 for fishing mortality, while “latest” is 2018. The values of the upper 90th and lower 10th percentiles of the empirical distributions are also shown. F_{mult} is the multiplier of recent (2014-2017) fishing mortality required to attain MSY.

	Mean	Median	Minimum	10th percentile	90th percentile	Maximum
C_{latest}	709,389	711,072	700,358	702,279	712,761	714,073
$Y_{Frecent}$	779,872	784,200	661,600	707,720	877,040	9080,00
f_{mult}	2.87	2.80	1.70	2.12	3.72	4.29
F_{MSY}	0.11	0.10	0.08	0.09	0.12	0.15
MSY	1,090,706	1,091,200	791,600	874,200	1,283,920	1,344,400
F_{recent}/F_{MSY}	0.37	0.36	0.23	0.27	0.47	0.59
$SB_{F=0}$	3,641,228	3,603,980	2,893,274	3,231,353	4,050,429	4,394,277
SB_{MSY}	860,326	858,700	349,100	590,090	1,114,400	1,322,000
$SB_{MSY}/SB_{F=0}$	0.23	0.24	0.12	0.18	0.28	0.30
$SB_{latest}/SB_{F=0}$	0.54	0.54	0.40	0.47	0.60	0.66
SB_{latest}/SB_{MSY}	2.43	2.28	1.47	1.67	3.29	4.89
$SB_{recent}/SB_{F=0}$	0.58	0.58	0.42	0.51	0.64	0.68
SB_{recent}/SB_{MSY}	2.59	2.43	1.58	1.77	3.57	5.27

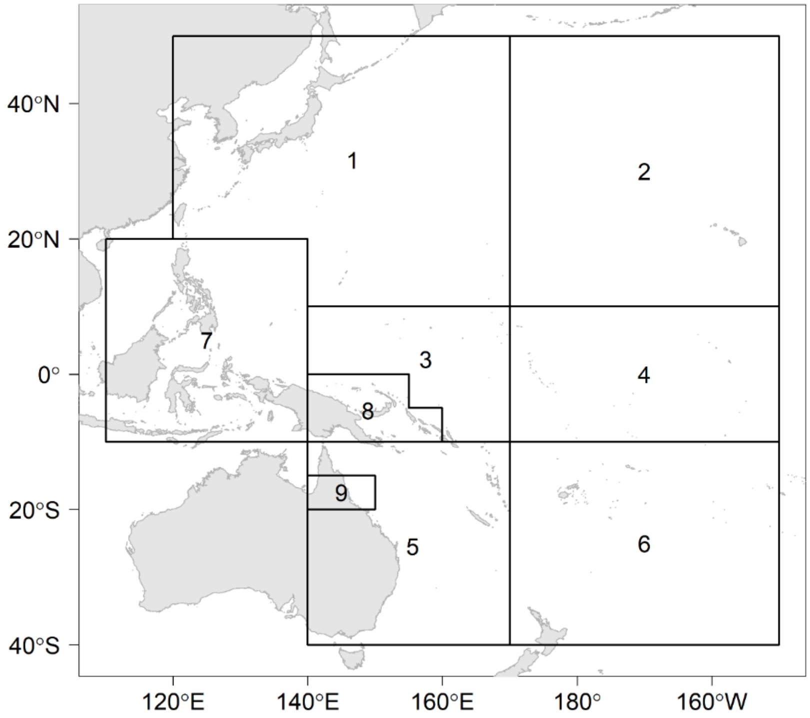


Figure YFT-1. The geographical area covered by the stock assessment and the boundaries for the 9 regions when using the "10N regional structure".

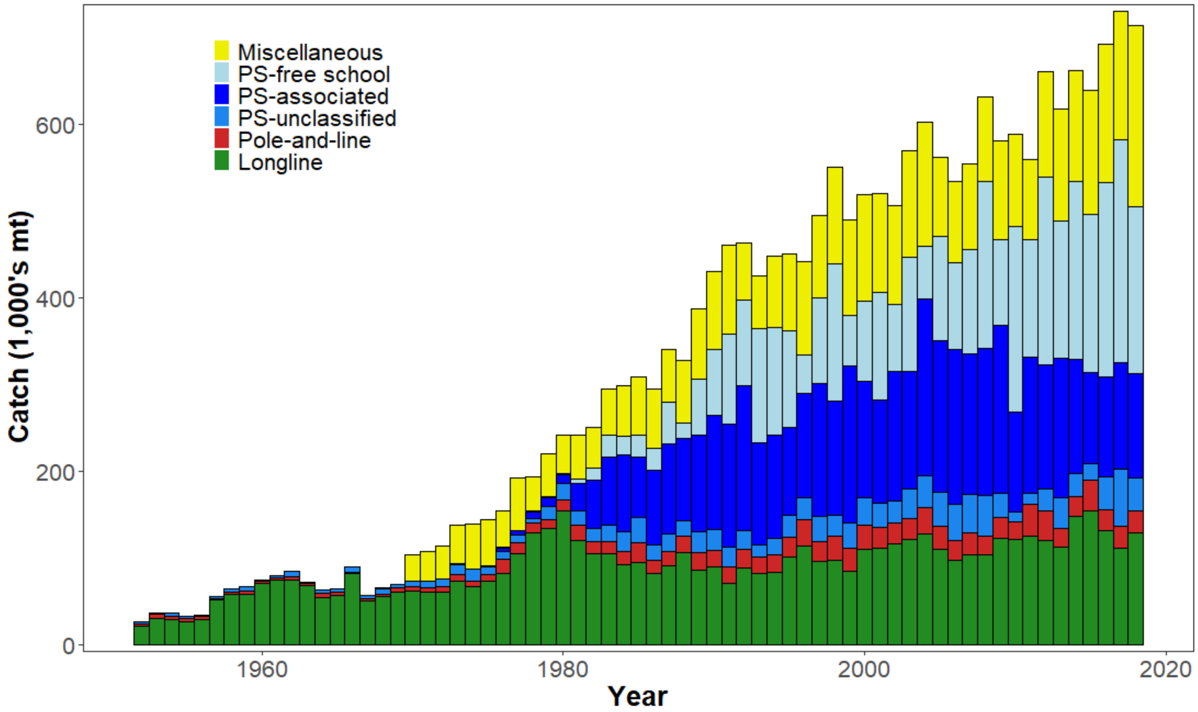


Figure YFT-2. Time series of total annual catch (1000s mt) by fishing gear over the full assessment region and time period. The different colours denote longline (green), pole-and-line (red), purse seine unclassified (blue), purse seine-associated (dark blue), purse seine-unassociated (light blue), miscellaneous (yellow).

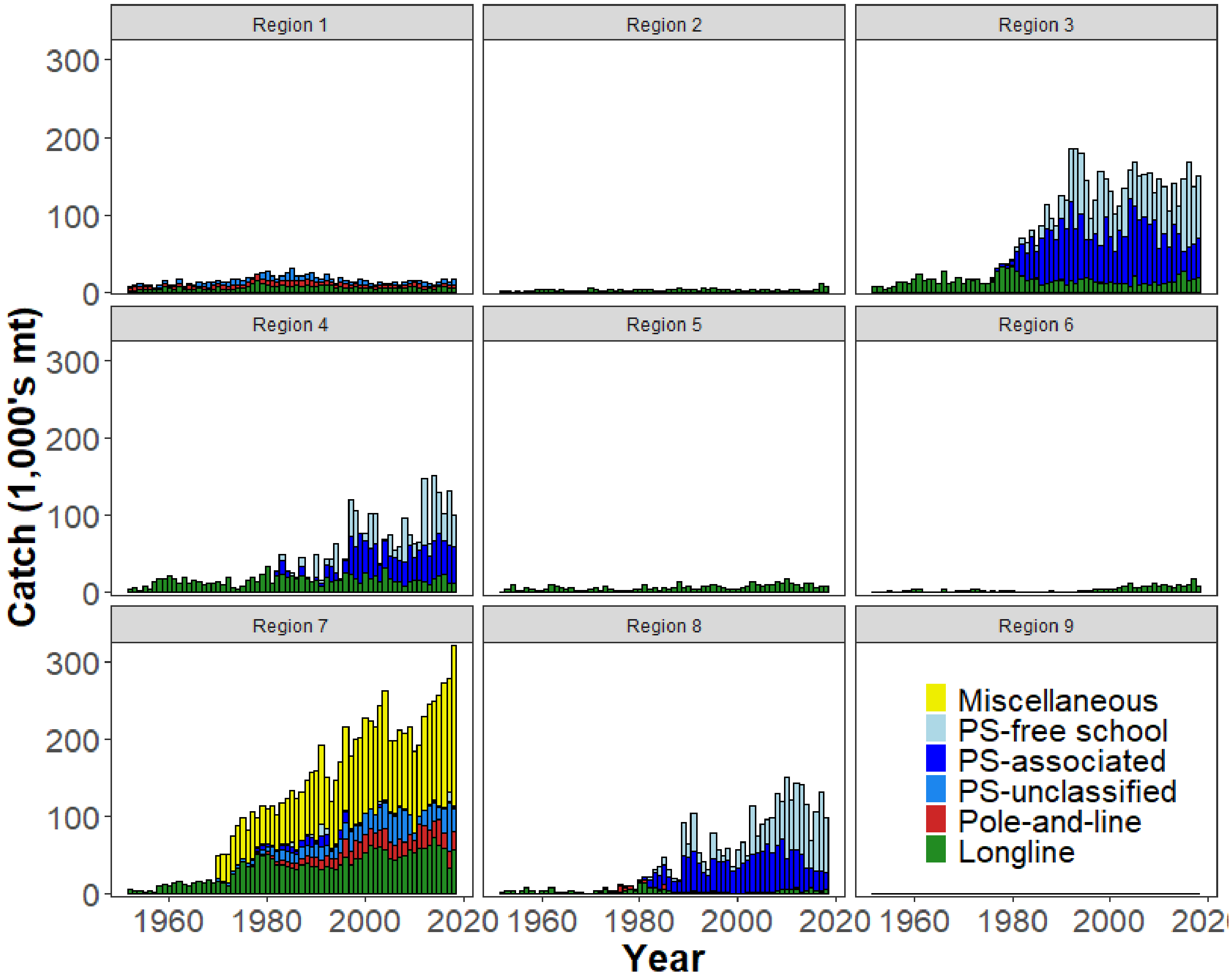
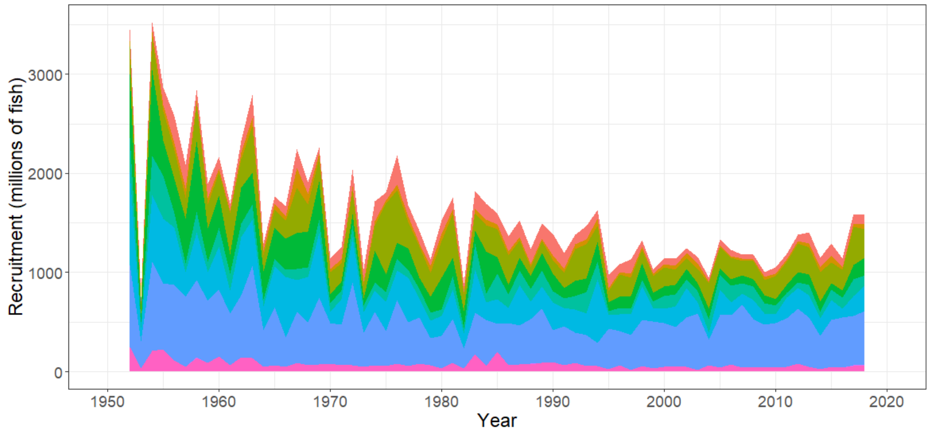
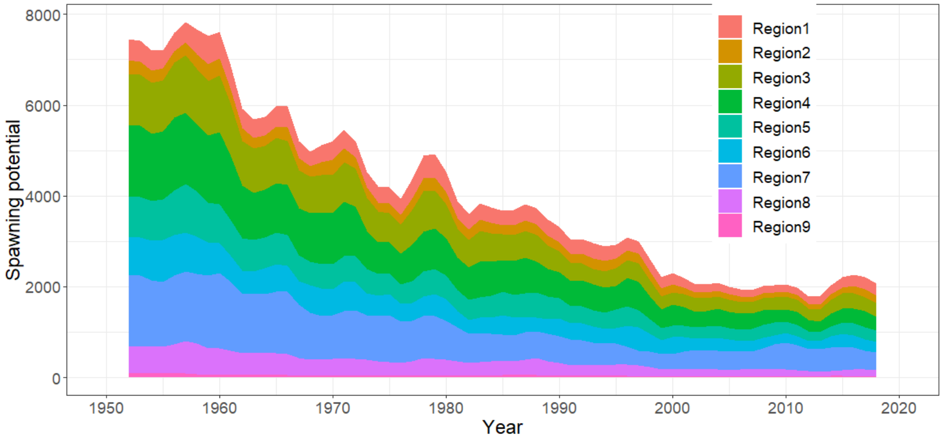


Figure YFT-3. Time series of total annual catch (1000s mt) by fishing gear and assessment region over the full assessment period. The different colours denote longline (green), pole-and-line (red), purse seine unclassified (blue), purse seine-associated (dark blue), purse seine-unassociated (light blue), miscellaneous (yellow).

(a) Recruitment



(b) Spawning Potential



(c) Total Biomass

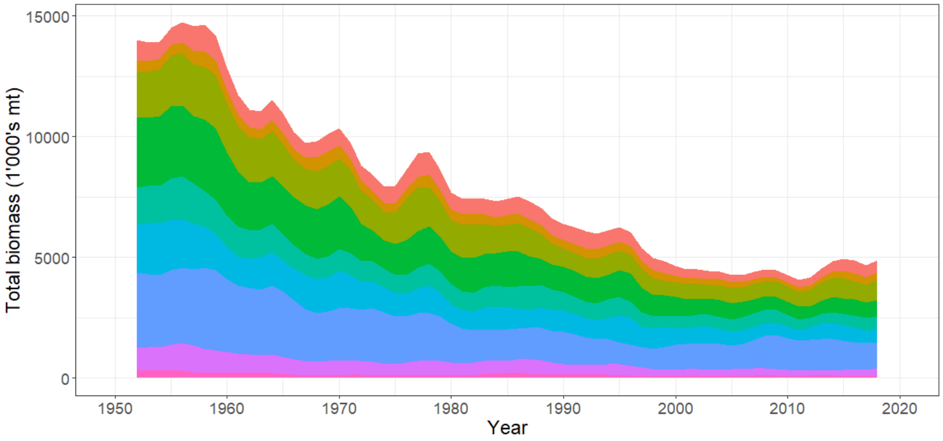


Figure YFT-4. Estimated annual average, (a) recruitment (b) spawning potential (c) total biomass by model region for the diagnostic model, showing the relative sizes among regions.

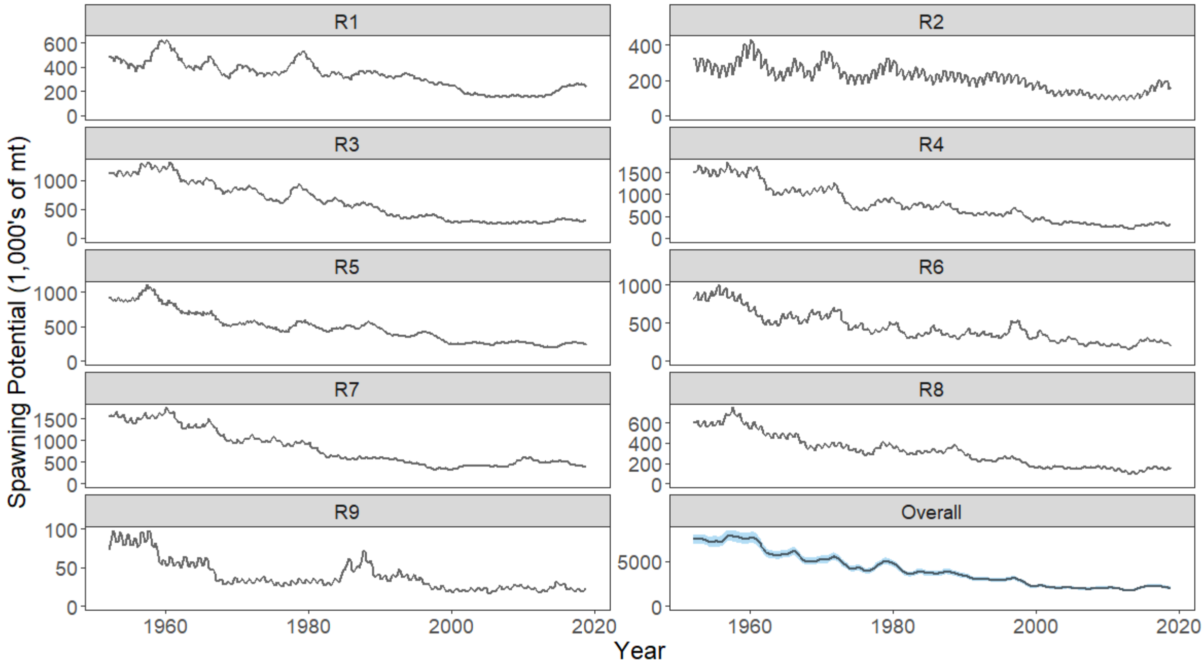


Figure YFT-5. The temporal trend in estimated spawning potential by model region for the diagnostic model, where the blue shaded region for the overall spawning potential shows the estimated 95% confidence interval based on statistical uncertainty estimated for the diagnostic model. Note that the y-axis scale among panels are not consistent.

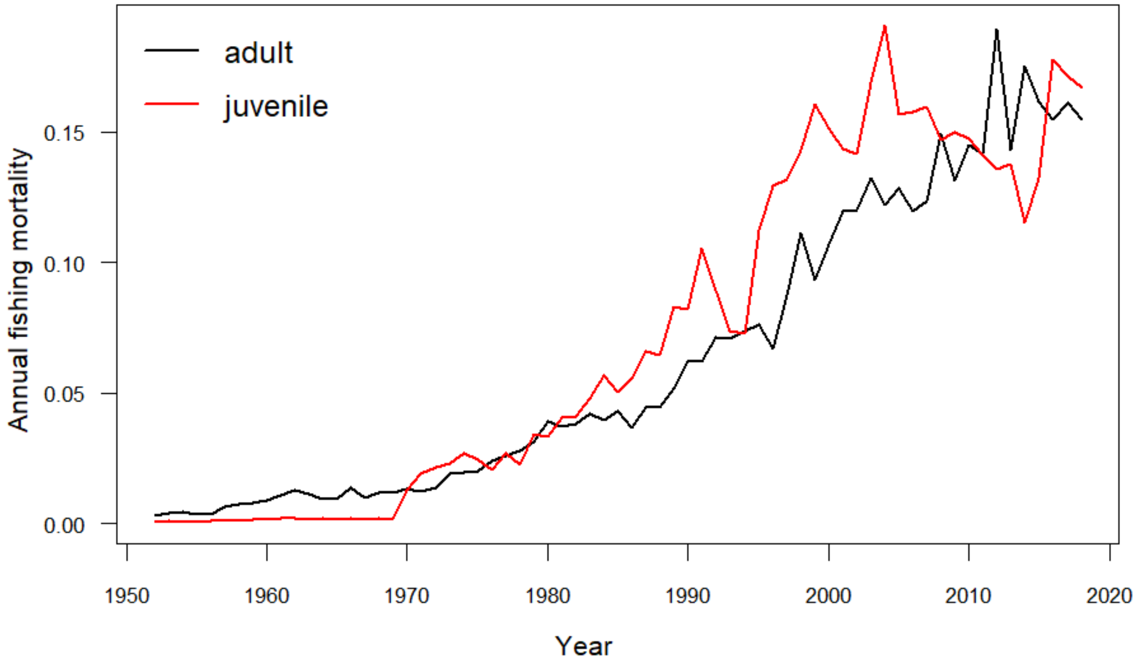


Figure YFT-6. Estimated annual average juvenile and adult fishing mortality for the diagnostic model.

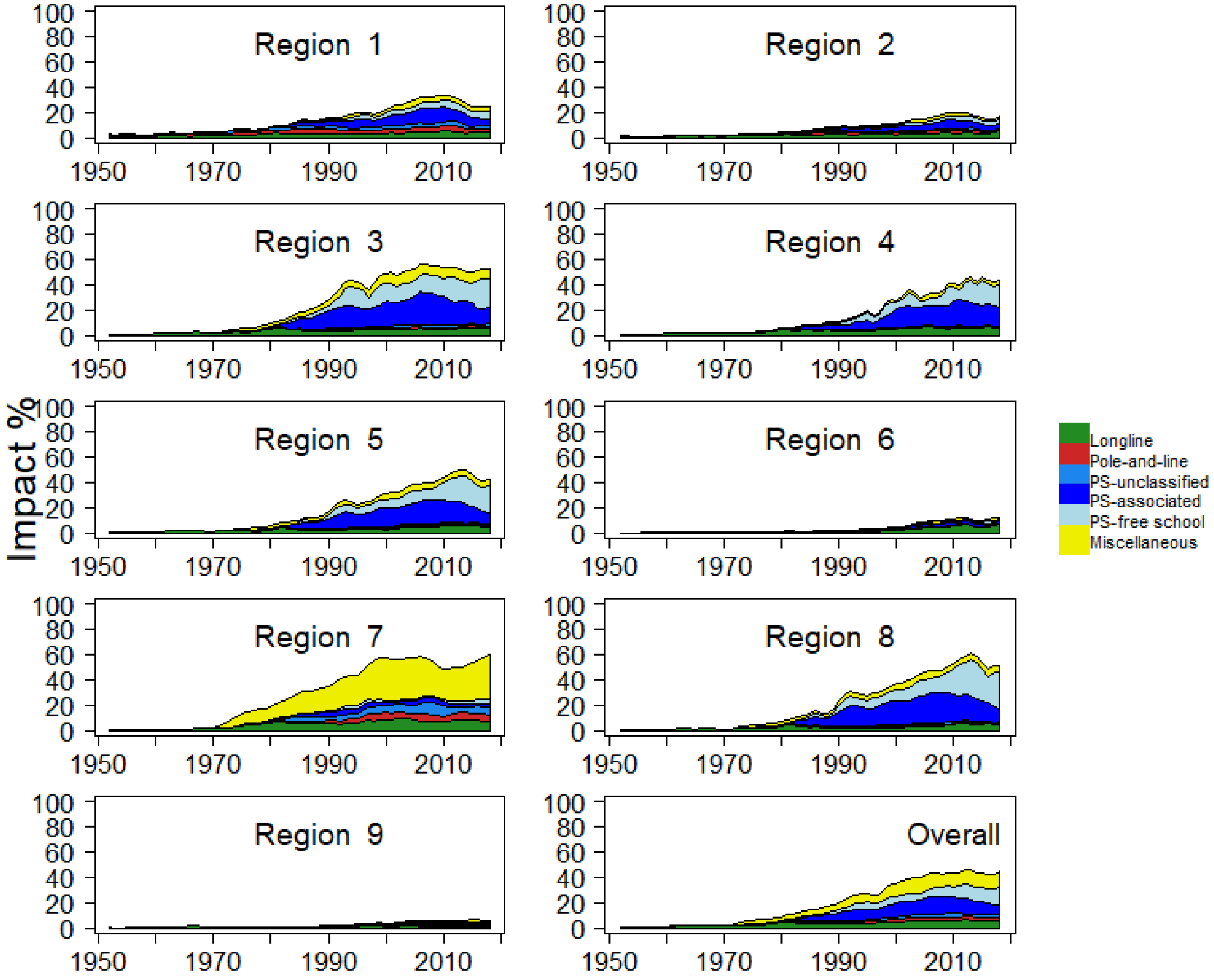


Figure YFT-7. Estimates of reduction in spawning potential due to fishing by region (Fishery Impact = (1-$SB_t/SB_{t;F=0}$) * 100%) and over all regions (lower right panel), attributed to various fishery groups for the diagnostic model.

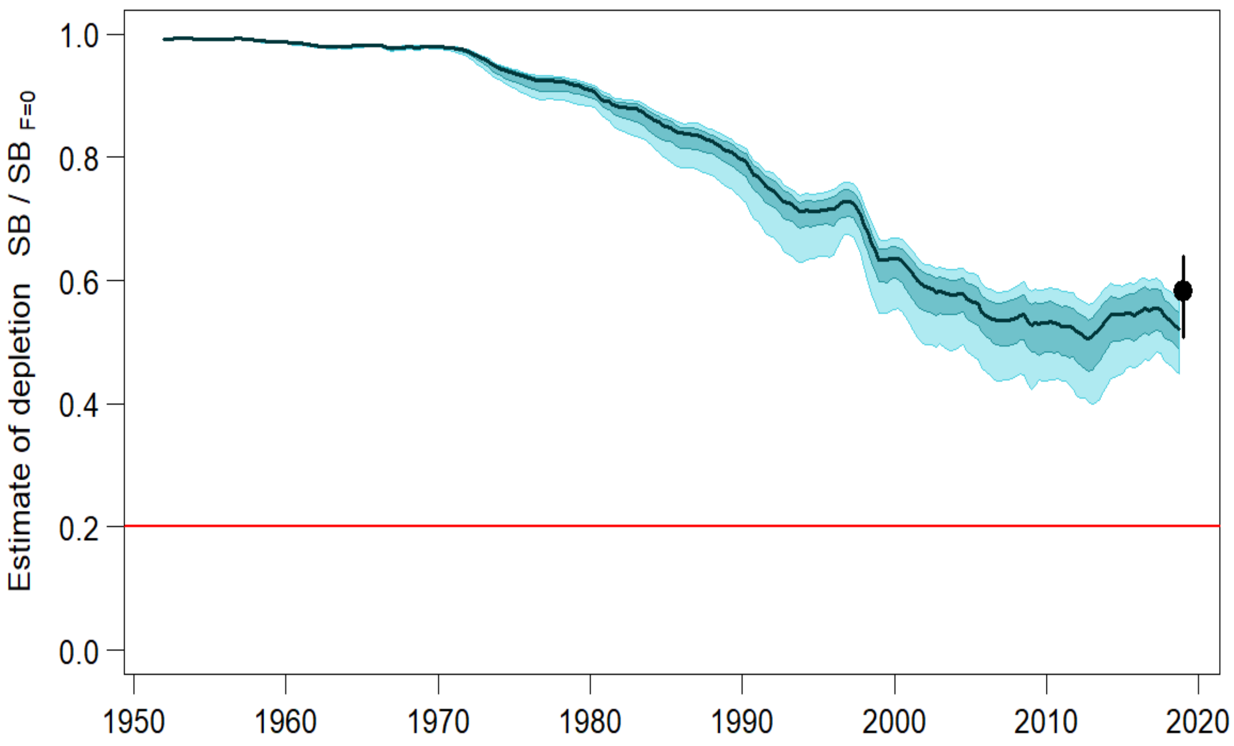


Figure YFT-8. Plot showing the trajectories of fishing depletion of spawning potential for the models in the structural uncertainty grid for the median, 50% quantile, and 80% quantile of instantaneous depletion across the structural uncertainty grid and the point and error bars is the median and 10th and 90th percentile of estimates of $SB_{recent}/SB_{F=0}$.

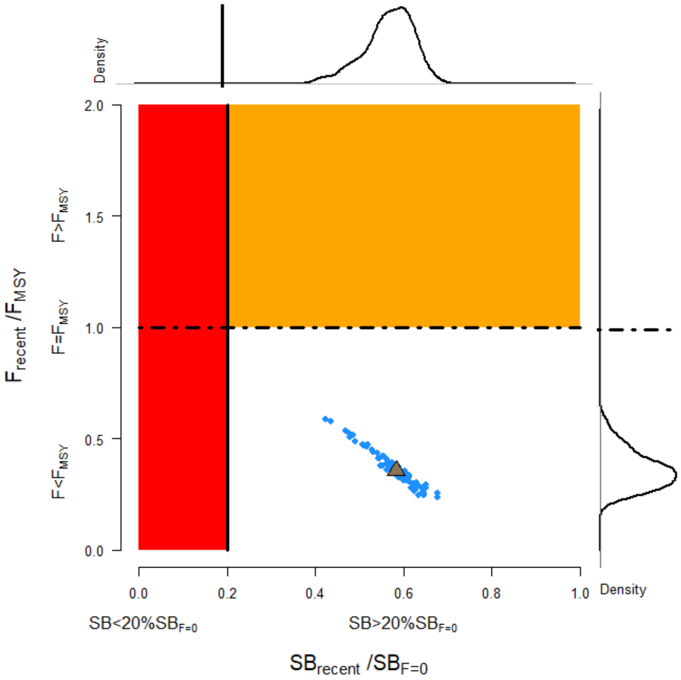


Figure YFT-9. Majuro plot representing stock status in terms of recent spawning potential depletion (2015–2018) and fishing mortality. The plots summarize the results for each of the models in the structural uncertainty grid with marginal distributions for spawning potential depletion and fishing mortality, where the brown triangle is the median of the structural uncertainty grid.

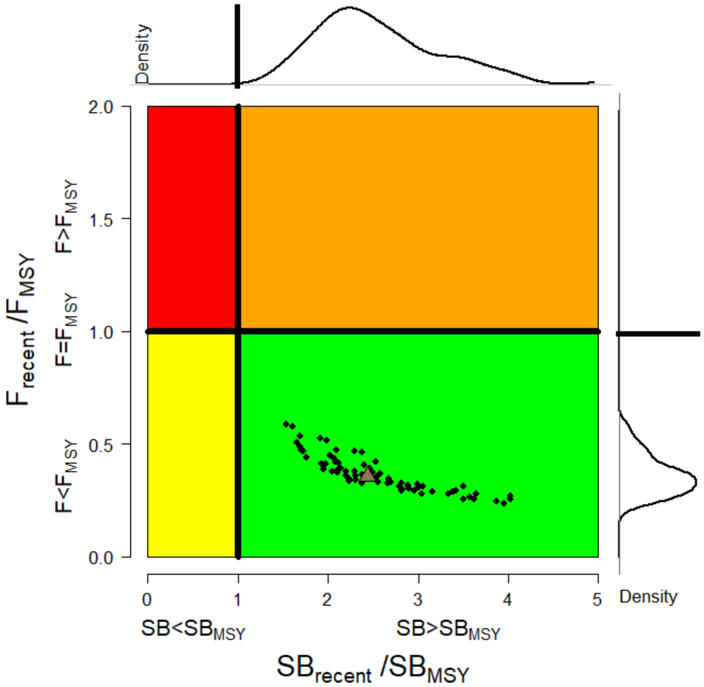


Figure YFT-10. Kobe plot for the recent spawning potential (2015–2018) summarizing the results for each of the models in the structural uncertainty grid. The plots represent estimates of stock status in terms of spawning biomass depletion and fishing mortality relative to MSY quantities and marginal distributions of each are presented with the median of the structural uncertainty grid displayed as a brown triangle.

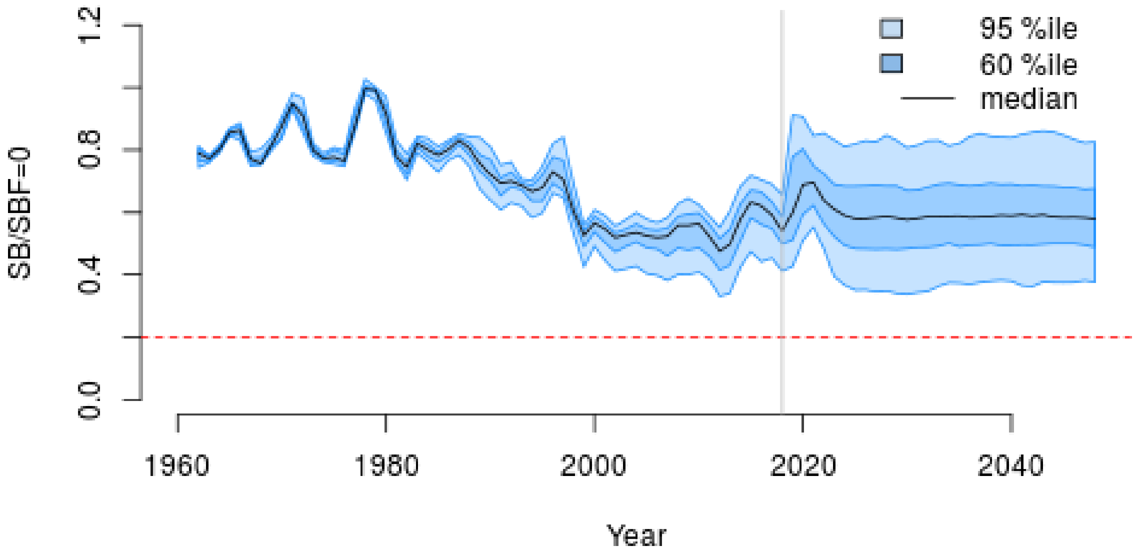


Figure YFT-11. Time series of yellowfin tuna spawning biomass ($SB_t/SB_{t,F=0}$, where $SB_{t,F=0}$ is the average SB from t-10 to t-1) from the uncertainty grid of assessment models for the period 2000 to 2018, and stochastic projection results for the period 2019 to 2048 assuming 2016-2018 average catches in LL and other fisheries and 2018 effort in PS fisheries continue. Vertical gray line at 2018 represents the last year of the assessment. During the projection period (2019-2048) levels of recruitment variability are assumed to match those over the time period used to estimate the stock-recruitment relationship (1962-2017). The red horizontal dashed line represents the agreed limit reference point.

4. SC16 noted that there has been a long-term decrease in spawning biomass from the 1970s for yellowfin tuna but that the depletion rates have been relatively stable over the last decade.

5. SC16 also noted that the median value of relative recent (2015-2018) spawning biomass depletion ($SB_{2015\text{-}2018}/SB_{F=0}$) was 0.58 with a 10th to 90th percentile interval of 0.51 to 0.64.

6. SC16 further noted that there was 0% probability (0 out of 72 models) that the recent (2015-2018) spawning biomass had breached the adopted LRP.

7. SC16 noted that there has been a long-term increase in fishing mortality for both juvenile and adult yellowfin tuna, which is consistent with previous assessments, but since 2010 there has been no directional trend.

8. SC16 noted that the median of relative recent fishing mortality ($F_{2014\text{-}2017}/F_{MSY}$) was 0.36 with a 10th to 90th percentile interval of 0.27 to 0.47.

9. SC16 further noted that there was 0% probability (0 out of 72 models) that the recent (2014-2017) fishing mortality was above F_{MSY}.

10. SC16 noted the results of stochastic projections (Figure YFT-11) from the 2020 assessment which indicated the potential stock consequences of fishing at “status quo” conditions (2016–2018 average

longline and other fishery catch and 2018 purse seine effort levels) and long-term recruitment scenario using the uncertainty framework approach endorsed by SC. Projections indicate that median $SB_{2025}/SB_{F=0}$ = 0.58; median $SB_{2035}/SB_{F=0}$ = 0.59 and median $SB_{2045}/SB_{F=0}$ = 0.58. The risk that $SB_{2048}/SB_{F=0}$ is less than the Limit Reference Point is 0%.

b. Management advice and implications

11. SC16 noted that the preliminary estimate of total catch of WCPO yellowfin tuna for 2019 was 669,362 mt, a 5% decrease from 2018 and a 1% increase from the average 2014-2018. Purse seine catch in 2019 (364,571 mt) was a 4% decrease from 2018 and an 8% decrease from the 2014-2018 average. Longline catch in 2019 (104,440 mt) was a 7% increase from 2018 and a 9% increase from the 2014-2018 average. Pole and line catch (37,563 mt) was a 43% increase from 2018 and a 40% increase from the average 2014-2018 catch. Catch by other gear totalled 162,788 t and was an 18% decrease from 2018 and a 16% increase from the average catch in 2014-2018.

12. SC16 noted that the catch in the last year of the assessment (2018) was 711,072 mt which was less than the median MSY (1,091,200 mt).

13. Based on the uncertainty grid adopted by SC16, the WCPO yellowfin tuna spawning biomass is above the biomass LRP and recent F is below F_{MSY}. The stock is not experiencing overfishing (100% probability $F<F_{MSY}$) and is not in an overfished condition (0% probability $SB/SB_{F=0}$<LRP). Additionally, stochastic projections predict there to be no risk of breaching the LRP (0% probability $SB_{2048}/SB_{F=0}$<LRP).

14. SC16 also noted that levels of fishing mortality and depletion differ between regions, and that fishery impact was highest in the tropical region (Regions 3, 4, 7 and 8 in the stock assessment model), mainly due to the purse seine fisheries in the equatorial Pacific and the “other” fisheries within the Western Pacific. There is also evidence that the overall stock status is buffered with biomass kept at a more elevated level overall by low exploitation in the temperate regions (1, 2, 6, and 9). SC16 therefore re-iterates that WCPFC17 could consider measures to reduce fishing mortality from fisheries that take juveniles, with the goal to increase fishery yields and reduce any further impacts on the spawning potential for this stock in the tropical regions.

15. SC16 noted that the 2020 stock assessment results indicate the stock is currently exploited at relatively low levels (median F/F_{MSY} = 0.36, 10th to 90th percentile interval 0.27-0.47). Nevertheless, SC16 recommends that the Commission notes that further increases in YFT fishing mortality would likely affect other stocks/species which are currently moderately exploited due to the multispecies/gears interactions in WCPFC fisheries taking YFT.

16. SC16 also noted that although the structural uncertainty grid presents a positive indication of stock status, the high level of unresolved conflict amongst the data inputs used in the assessment suggests additional caution may be appropriate when interpreting assessment outcomes to guide management decisions.

17. Based on those results, SC16 recommends as a precautionary approach that the fishing mortality on yellowfin tuna stock should not be increased from the level that maintains spawning biomass at 2012-2015 levels until the Commission can agree on an appropriate target reference point.

Attachment 3

The Commission for the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean

Scientific Committee
Eighteenth Regular Session

Electronic Meeting
10–18 August 2022

WCPO SKIPJACK TUNA STOCK ASSESSMENT

(Paragraphs 5 – 23, SC18 Outcomes Document)

Provision of scientific information

a. ***Status and trends***

1. SC18 noted that the total catch in 2021 was 1,547,945t, a 10% decrease from 2020 and a 14% decrease from the 2016-2020 average. Purse seine catch in 2021 (1,254,022t) was a 11% decrease from 2020 and a 13% decrease from the 2016-2020 average. Pole and line catch (97,908t) was a 39% decrease from 2020 and a 37% decrease from the 2016-2020 average catch. Catch by other gears totalled 192,182t and was a 25% increase from 2020 and 5% decrease from the average catch in 2016-2020.

2. SC18 adopted the 2022 assessment and a structural uncertainty grid was used to develop management advice which included axes for tag mixing (three options), growth (two options) and steepness (three options), resulting in 18 models (Table SKJ-01). All models within the grid were equally weighted. The assessment grid of models estimated that the overall median recent spawning depletion ($SB_{recent}/SB_{F=0}$) is 0.51 (80th percentile 0.43-0.64), which is close to the interim target reference point (TRP) of 0.50 (CMM 2021-01). No grid models were below the limit reference point (LRP) of 0.20 $SB_{F=0}$. The median of F_{recent}/F_{MSY} was 0.32 (80th percentile 0.18-0.45) (Table SKJ-02). The 2022 stock assessment of skipjack tuna for the WCPO, indicated that according to WCPFC reference points the stock is not overfished, nor undergoing overfishing.

3. Catches of skipjack tuna in the WCPO have increased from approximately 250,000 metric tonnes in the late 1970s to a peak catch of approximately 2,000,000 metric tonnes in 2019; catches have dropped from 2019 to 2021 (Figure SKJ-02). Catches are dominated by purse seine fisheries in equatorial regions 6, 7, and 8, and purse seine and other gears in region 5 (Figure SKJ-03). Catches are dominated by pole-and-line in the northern regions 1–4 and continue to be low compared to those in the equatorial regions (Figures SKJ-03 and SKJ-04). The spawning potential and total biomass, while showing variability over time, do not show sustained long-term declining trends (Figures SKJ-05 and SKJ-08). In contrast, the trajectory of spawning potential depletion ($SB/SB_{F=0}$) shows a long-term trend towards a more depleted status (Figure SKJ-09). The spawning potential depletion trajectory was largely driven by the model estimates of increased levels of unfished spawning potential over time which are in turn driven by the model estimates of increasing recruitment over time (Figure SKJ-05). The model estimated increased recruitment over time to account for the increased catches in the face of a relatively stable biomass that is partly informed by several long-term stable CPUE indices of abundance (i.e., pole-and-line fishery indices) within the assessment. However, it is noted that spawning potential, recruitment and total biomass are estimated to have declined since around 2010 (Figure SKJ-05).

4. Fishing mortality continues to increase over time for the adult and juvenile components of the stock,

with fishing mortality being consistently higher for adults (Figure SKJ-06).

5. Fishery impact analyses show that the purse seine fisheries continue to dominate the impact in the equatorial regions 6, 7, and 8, with similar impacts by the ‘associated’ and ‘unassociated’ components, except for region 8 where ‘associated’ fishing appears to have more impact (Figure SKJ-07). Fishery impacts in region 5 are dominated by purse seine and other gears, and in regions 1-4, by pole-and-line, but with increasing impact of purse seine over time (Figure SKJ-07).

6. The influences of the structural uncertainty grid axes on key management quantities are shown in Figure SKJ-10. Tag mixing assumptions that applied longer tag mixing periods, and the externally estimated growth curve, resulted in more optimistic estimates of spawning potential depletion and spawning potential and lower fishing mortality.

7. Majuro and Kobe plots summarising stock status for the 18 models in the structural uncertainty grid are included for the ‘latest’ (2021, Figure SKJ-11) and ‘recent’ periods (2018-2021, Figure SKJ-12). These plots show that the stock status estimates across the 18 models are all within the zones indicating that the stock is not overfished nor undergoing overfishing.

8. The assessment provided a range of diagnostic analyses derived from the diagnostic model that indicated conflict between tag and CPUE data and instability in the convergence minima. Despite this, the model showed low retrospective bias and the important spawning potential depletion management quantities were robust to the differences in model convergence. However, as noted by several CCMs, data conflicts and the instability in model convergence minima require follow-up work and should be improved.

Table SKJ-01. Structural uncertainty grid for the 2022 WCPO skipjack tuna stock assessment. Bold values indicate settings for the diagnostic case.

Axis	Levels	Option 1	Option 2	Option 3
Tag mixing	3	T1, D=0.1 (longer period)	**T2,** D=0.2 (intermediate)	T3, D=0.3 (shorter)
Growth	2	**G1,** Internally estimated (Dirichlet-multinomial)	G2, Externally estimated (otolith and tagging data)	
Steepness	3	0.65	**0.8**	0.95

Table SKJ-02. Summary of reference points over the 18 individual models in the structural uncertainty grid.

	Mean	Median	Min	10%ile	90%ile	Max	Diagnostic model
C_{latest}	1530209	1530208	1530207	1530207	1530212	1530212	1530207
F_{MSY}	0.23	0.23	0.18	0.19	0.27	0.28	0.24
fmult	3.61	3.18	1.88	2.22	5.54	8.08	2.86
F_{recent}/F_{MSY}	0.32	0.32	0.12	0.18	0.45	0.53	0.35
MSY	2933489	2648400	2046000	2167840	4777200	4868000	2416000
SB_0	7958888	7204500	5317000	5611000	12842000	14390000	5686000
$SB_{F=0}$	8073171	7616930	5953338	6156944	12310363	12744728	6147339
SB_{latest}/SB_0	0.48	0.48	0.37	0.41	0.56	0.60	0.48
$SB_{latest}/SB_{F=0}$	0.47	0.46	0.35	0.38	0.60	0.61	0.44
SB_{latest}/SB_{MSY}	2.82	2.68	1.65	1.95	3.81	4.62	2.54
SB_{MSY}	1419366	1335000	806300	870530	1984600	2925000	1073000
SB_{MSY}/SB_0	0.18	0.18	0.13	0.13	0.22	0.22	0.19
$SB_{MSY}/SB_{F=0}$	0.17	0.17	0.11	0.13	0.22	0.23	0.17
$SB_{recent}/SB_{F=0}$	0.52	0.51	0.41	0.43	0.64	0.66	0.50
SB_{recent}/SB_{MSY}	3.12	2.98	1.92	2.20	4.22	4.97	2.88
$Y_{Frecent}$	1896888	1892400	1621600	1683880	2116000	2282800	1762400
$(SB_{recent}/SB_{F=0})/(SB_{2012}/SB_{F=0})$	0.84	0.85	0.82	0.82	0.86	0.87	0.85

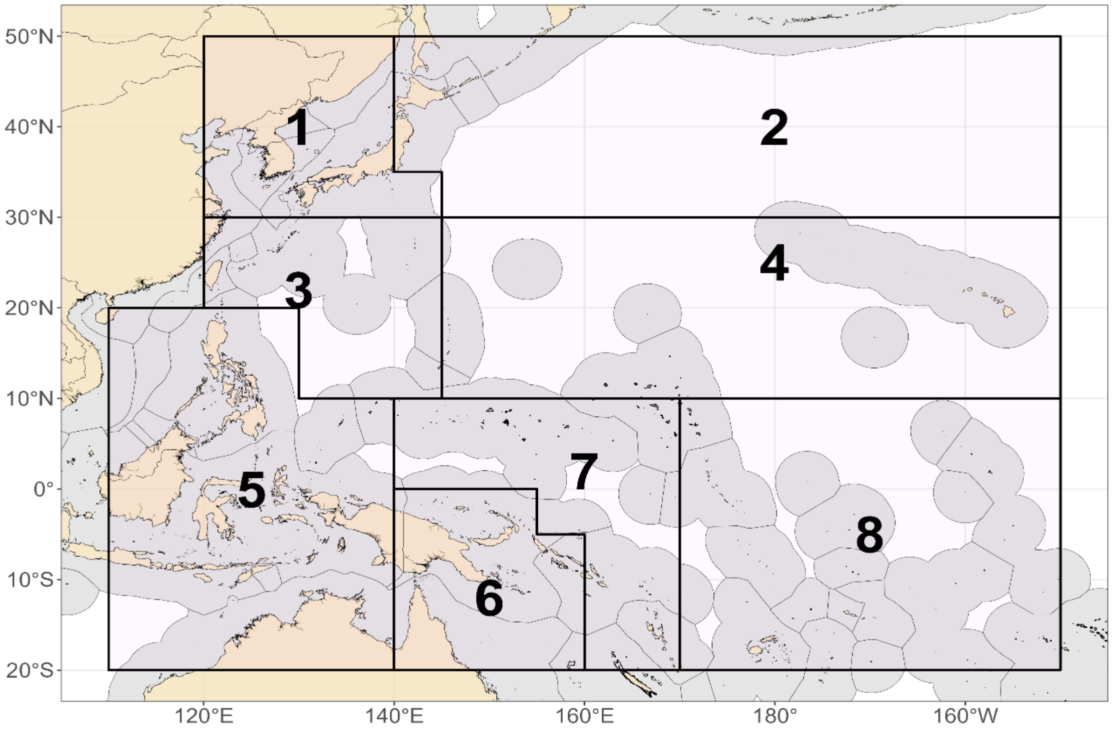


Figure SKJ-01. The geographical area covered by the stock assessment and the boundaries of the eight model regions used for 2022 WCPO skipjack assessment.

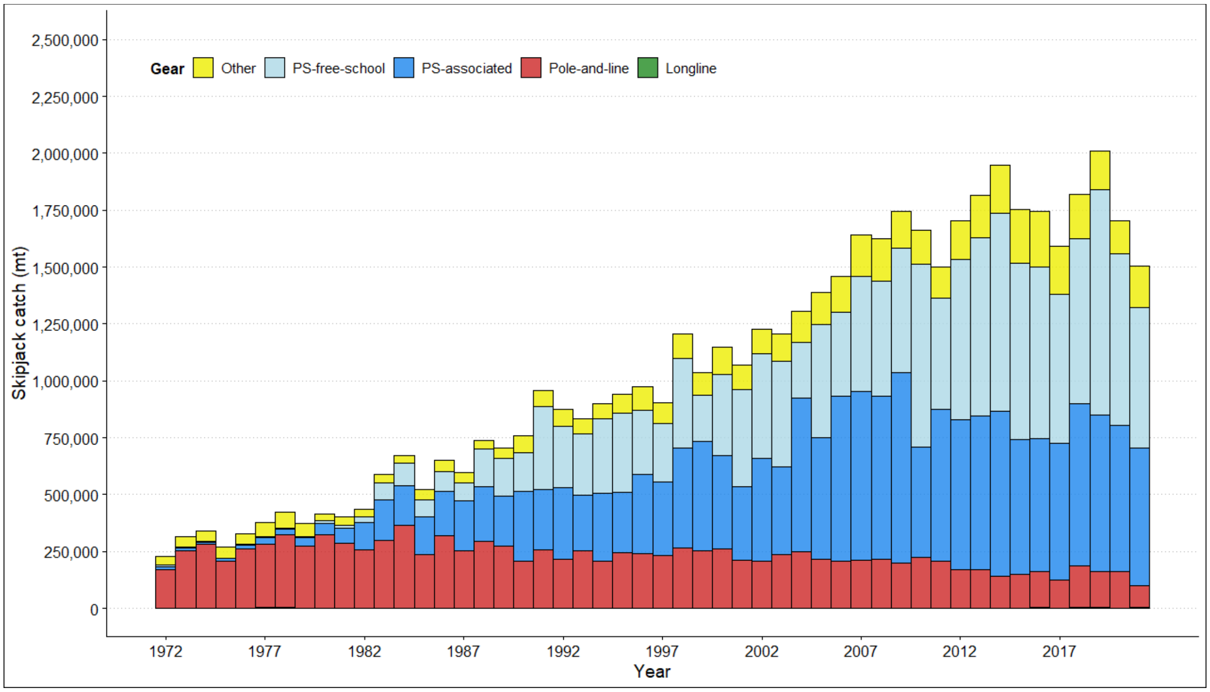


Figure SKJ-02. Annual catches of skipjack by gear type in the WCPO area covered by the assessment.

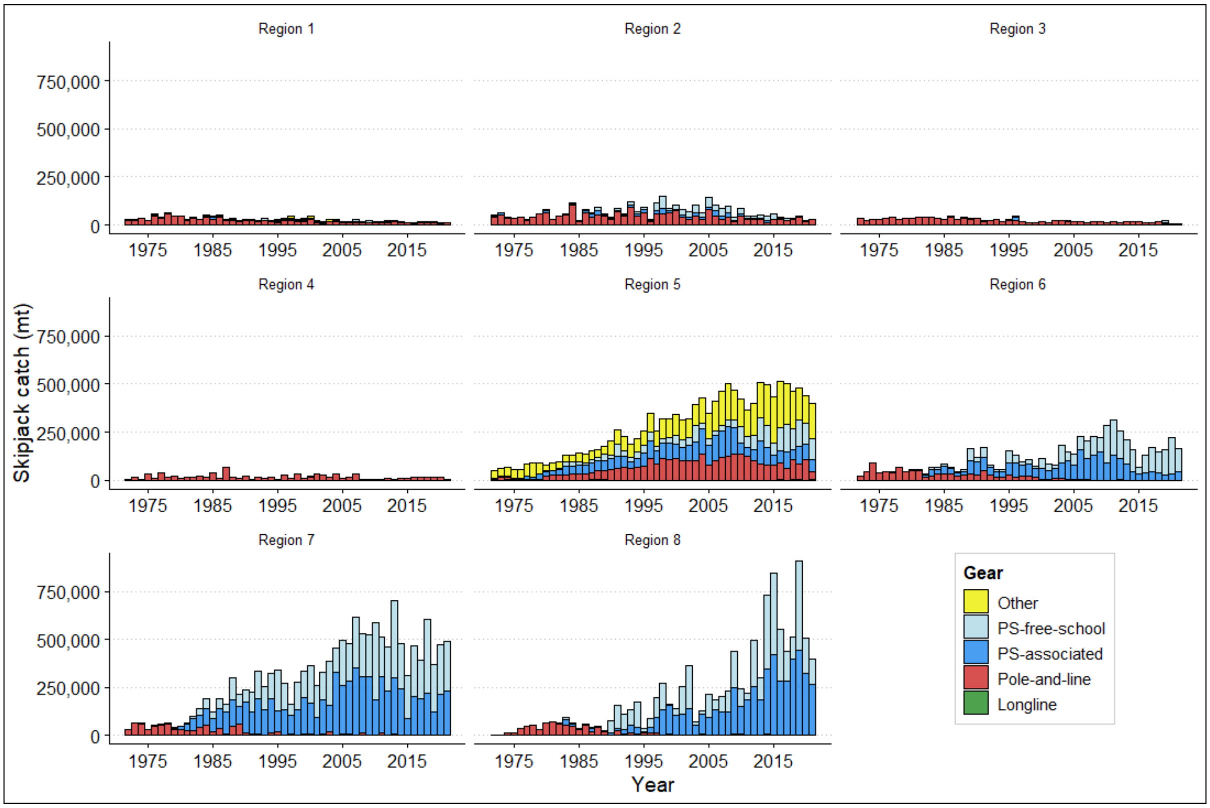


Figure SKJ-03. Annual catches of skipjack by gear type for each of the eight model regions.

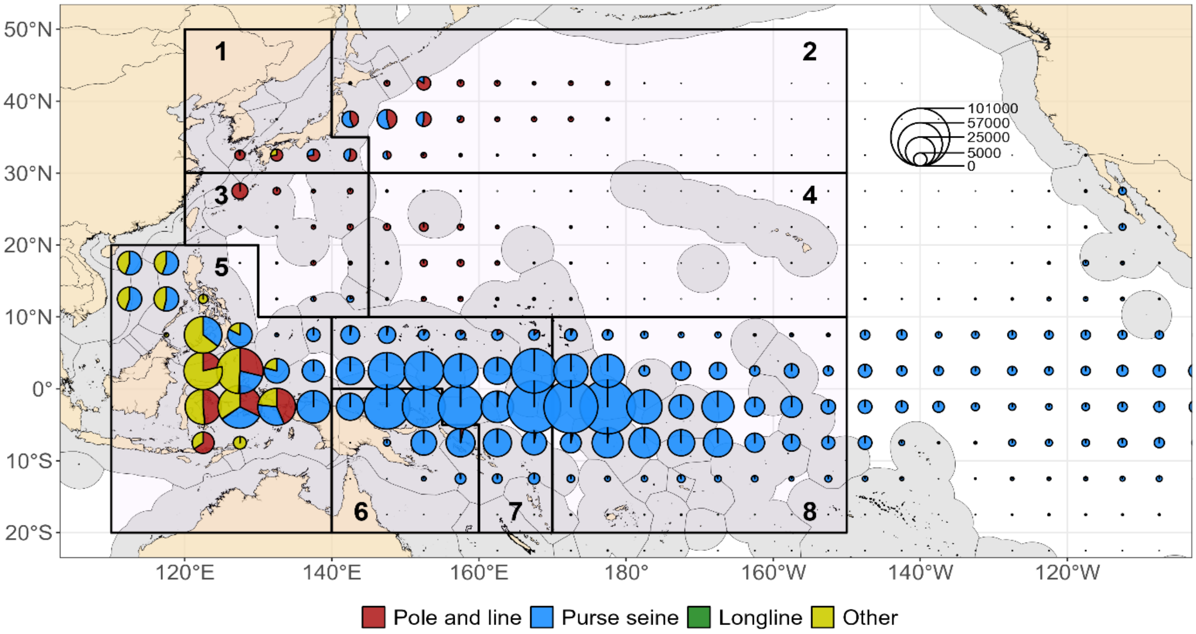


Figure SKJ-04. Distribution and magnitude of skipjack catches (mt) by gear type summed over the last 10 years (2012-2021) for 5 x 5 degree cells.

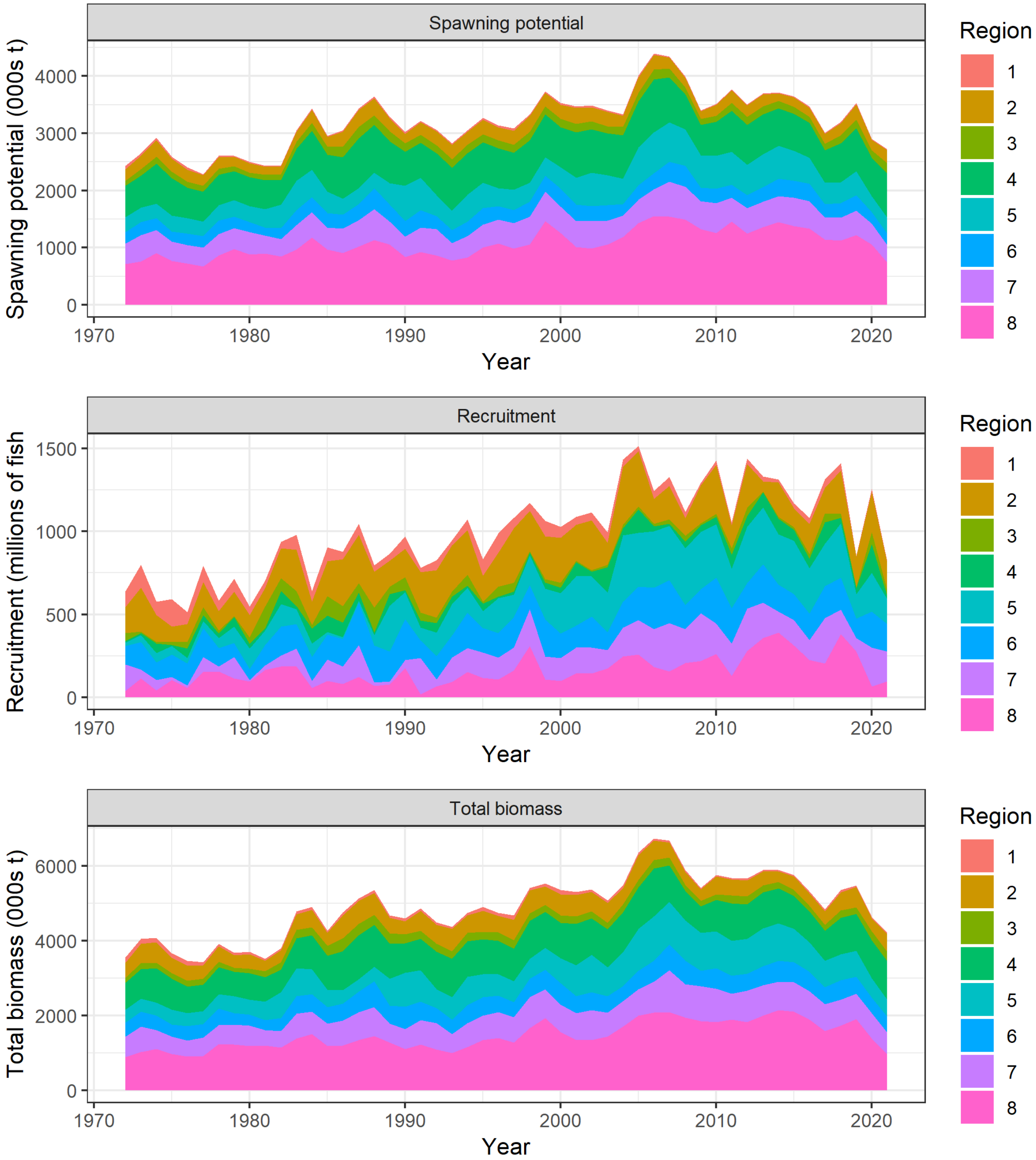


Figure SKJ-05. Estimated average quarterly recruitment, spawning potential and total biomass by model region from 1972-2021 for the 2022 skipjack diagnostic model, showing the relative proportions among regions.

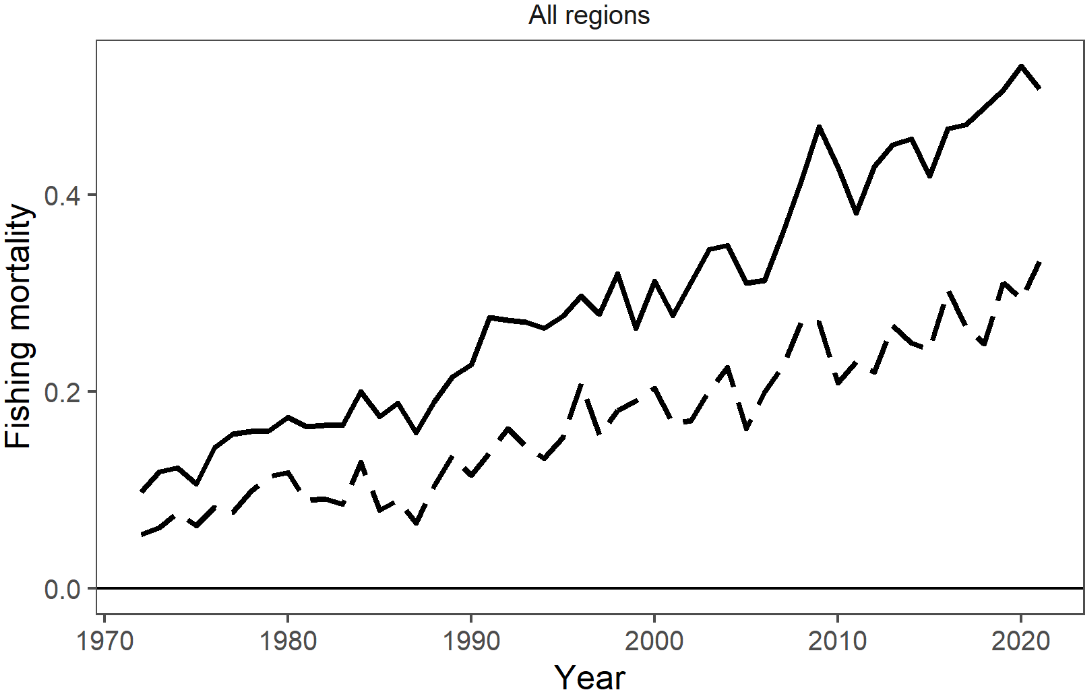


Figure SKJ-06. Estimated average quarterly adult (solid line) and juvenile (dashed line) fishing mortality for the diagnostic model from 1972-2021.

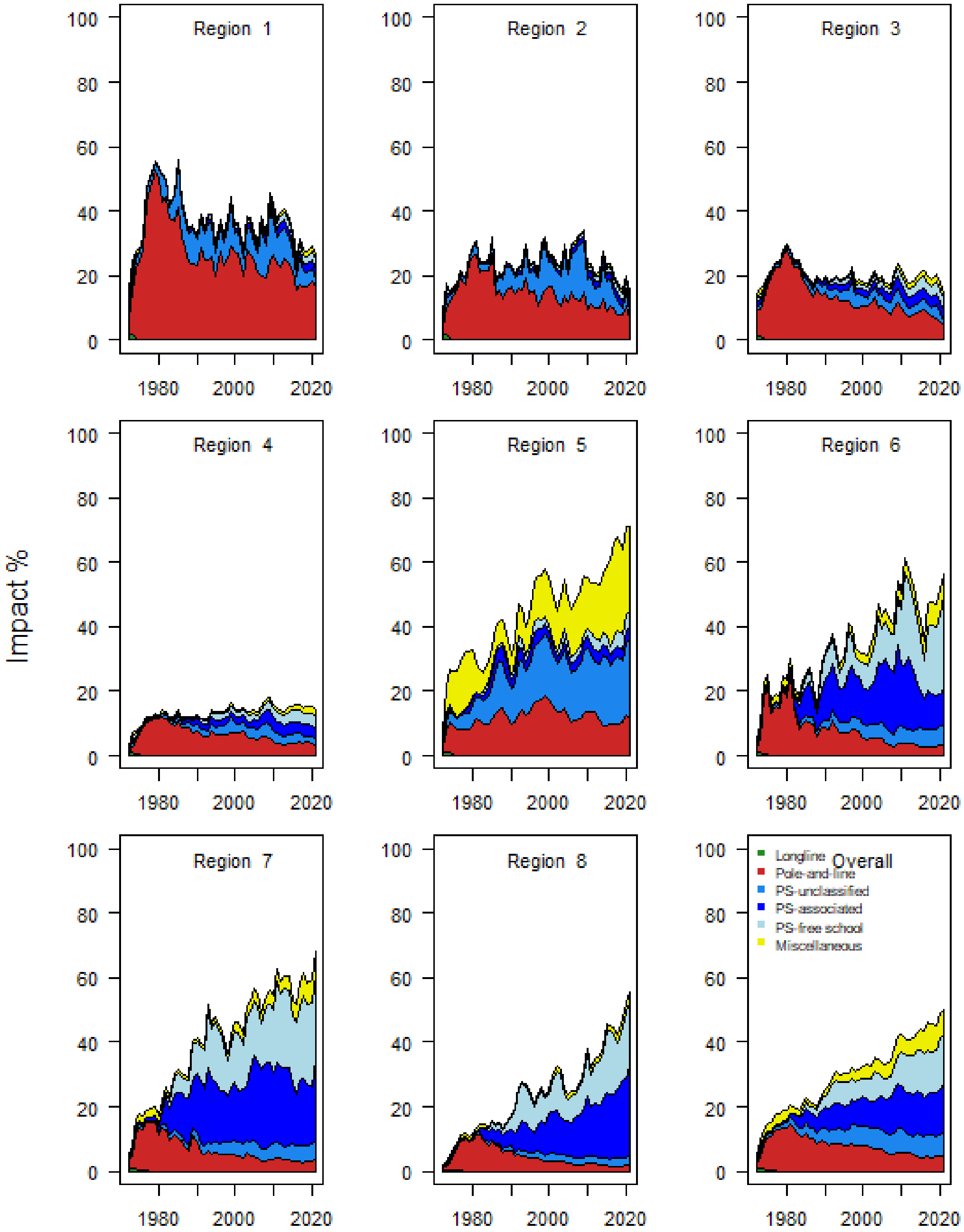


Figure SKJ-07. Estimates of reduction in spawning potential due to fishing (Fishery Impact = 1–*SB*$SB_{latest}/SB_{F=0}$) by region, and over all regions (lower right panel), attributed to various fishery groups for the diagnostic model.

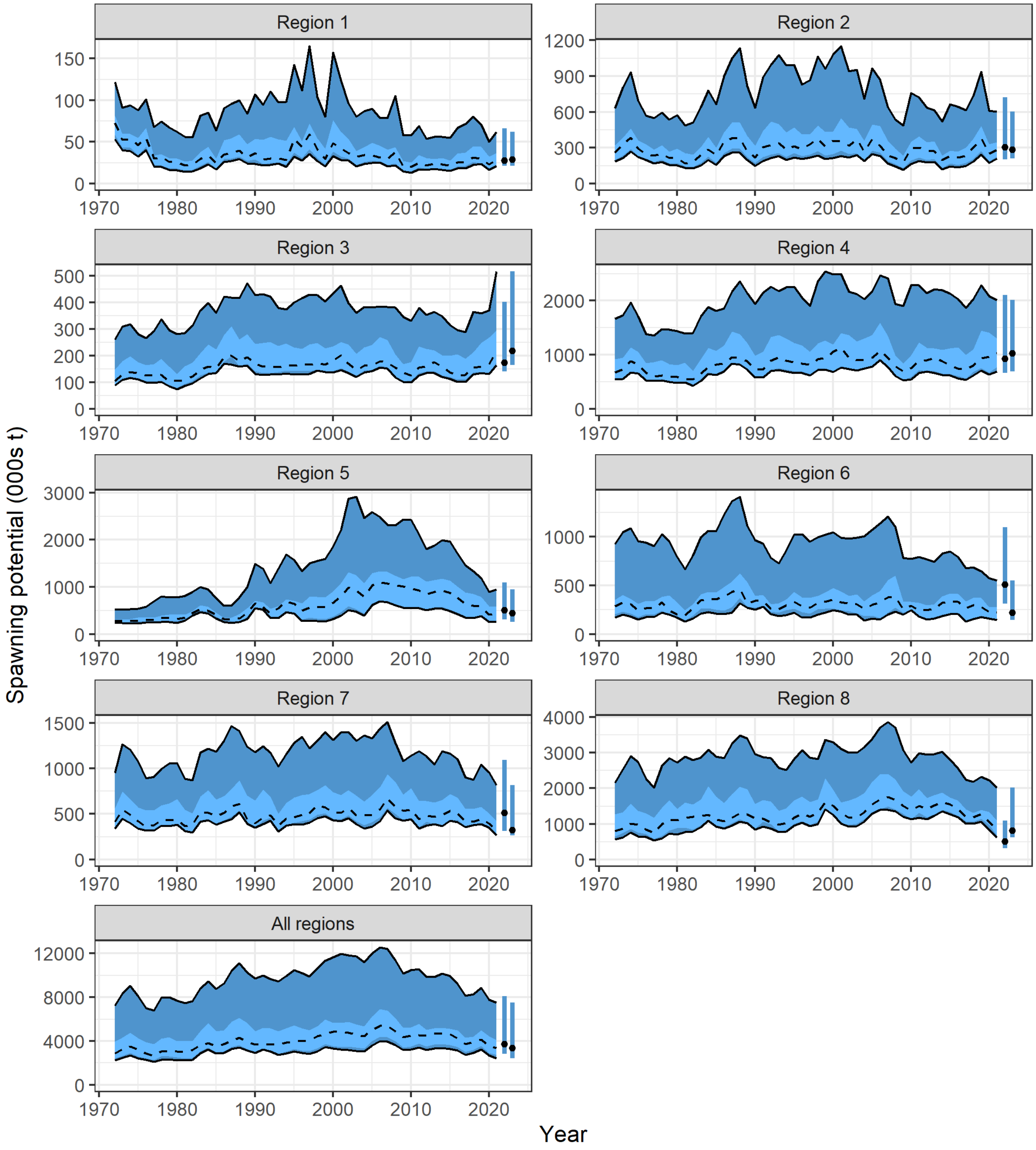


Figure SKJ-08. Trajectories of spawning potential (SB) across all models in the structural uncertainty grid over the period 1972-2021. The dashed line represents the median. The lighter band shows the 50th percentile, and the dark band shows the 80th percentile of the model estimates. The bars at the right of each ribbon indicate the median (black dots) and 80th percentile range for (left bar) SB_{recent} and (right bar) SB_{latest}.

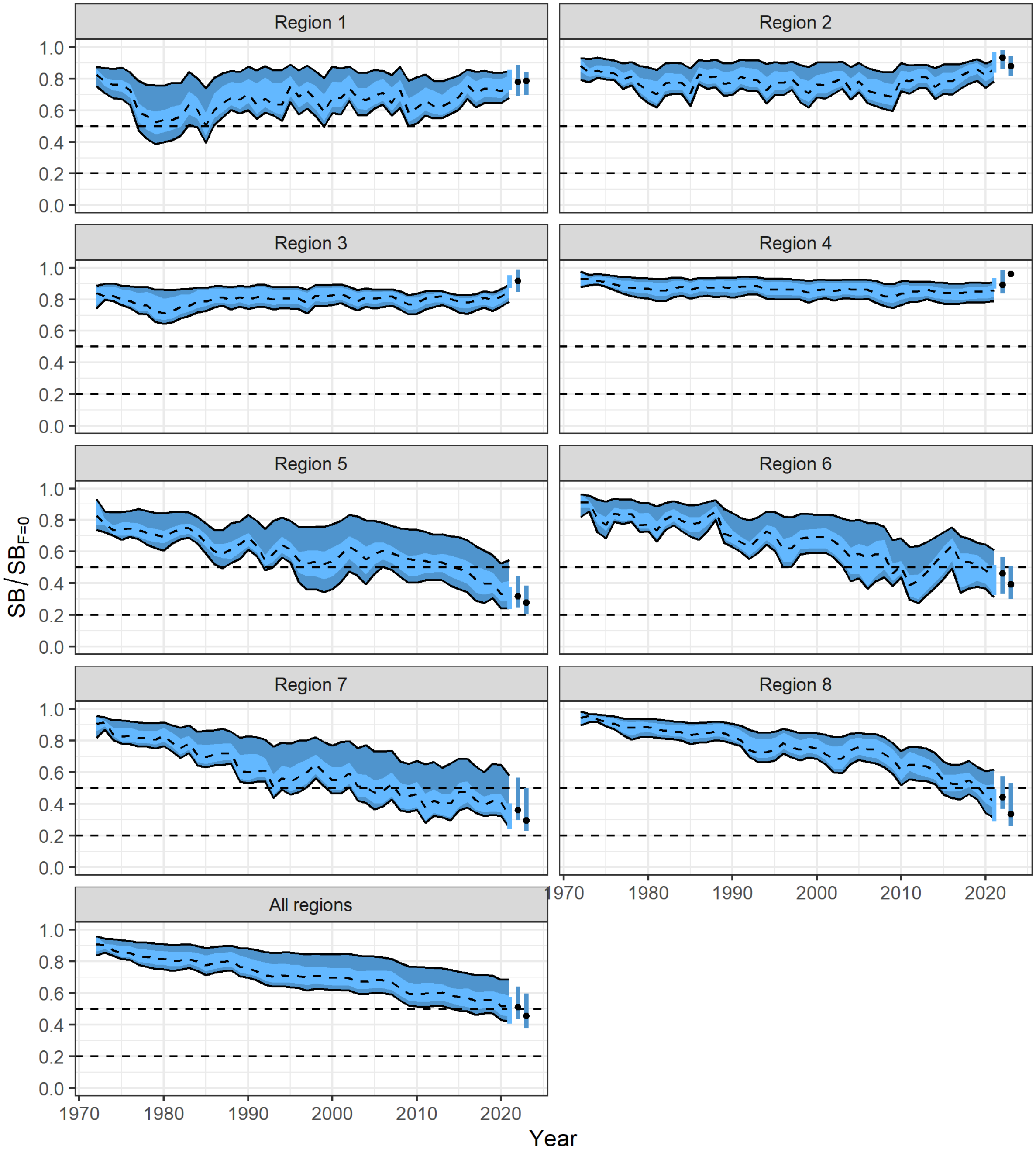


Figure SKJ-09. Trajectories of spawning potential depletion across all models in the structural uncertainty grid over the period 1972-2021. The dashed line represents the median. The lighter band shows the 50th percentile, and the dark band shows the 80th percentile of the model estimates. The bars at the right of each ribbon indicate the median (black dots) and 80th percentile range for (left bar) $SB_{recent}/SB_{F=0}$ and (right bar) $SB_{latest}/SB_{F=0}$.

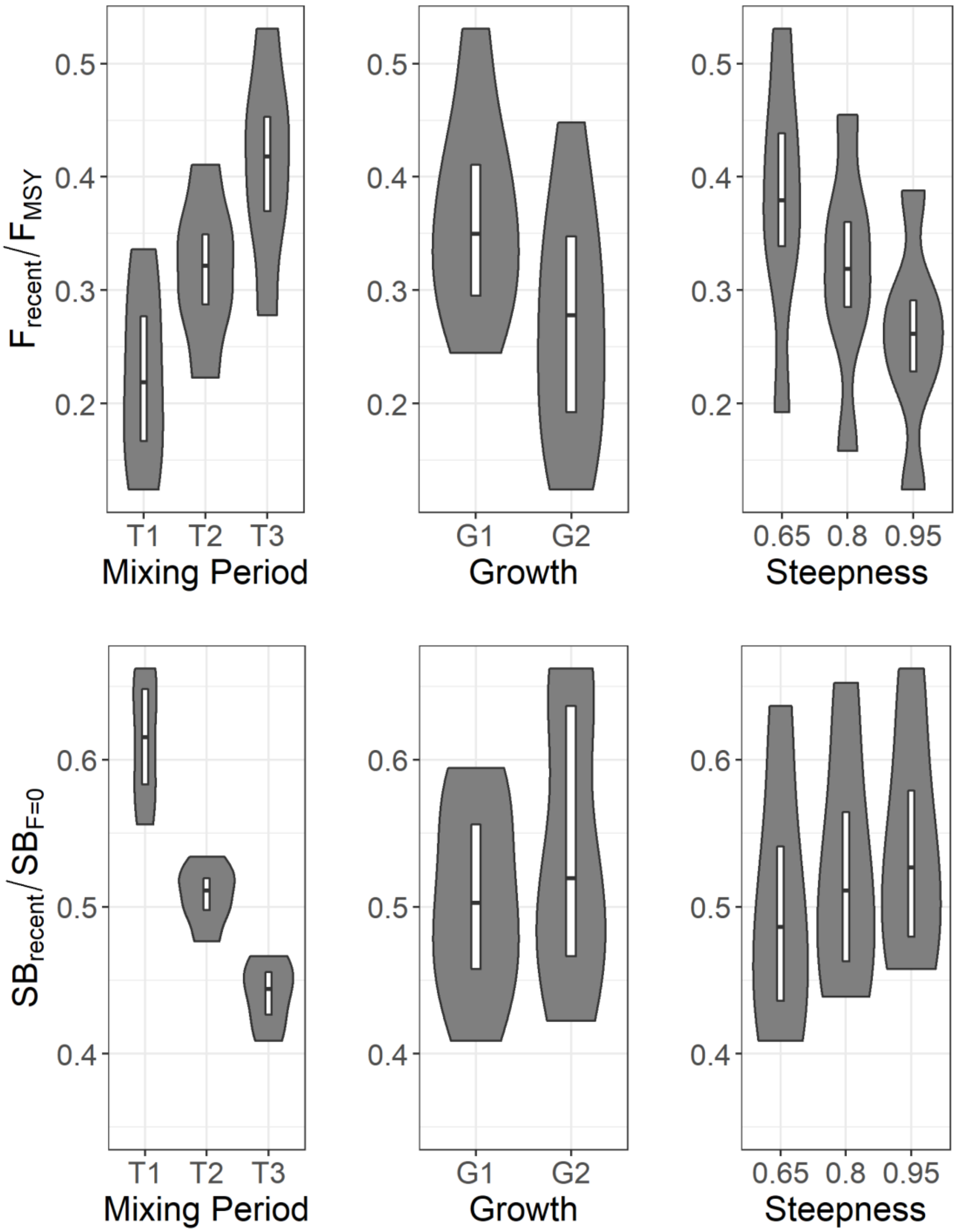


Figure SKJ-10. Box and violin plots summarizing (Top) the estimated F_{recent}/F_{MSY} and (Bottom) $SB_{recent}/SB_{F=0}$ for each of the models in the structural uncertainty grid grouped by uncertainty axes (growth, tag mixing and steepness). The line in the white box is the median of the estimates, while the box shows the 50th percentile. The shaded area shows the probability distribution (or density) of the estimates of all models of the structural uncertainty grid.

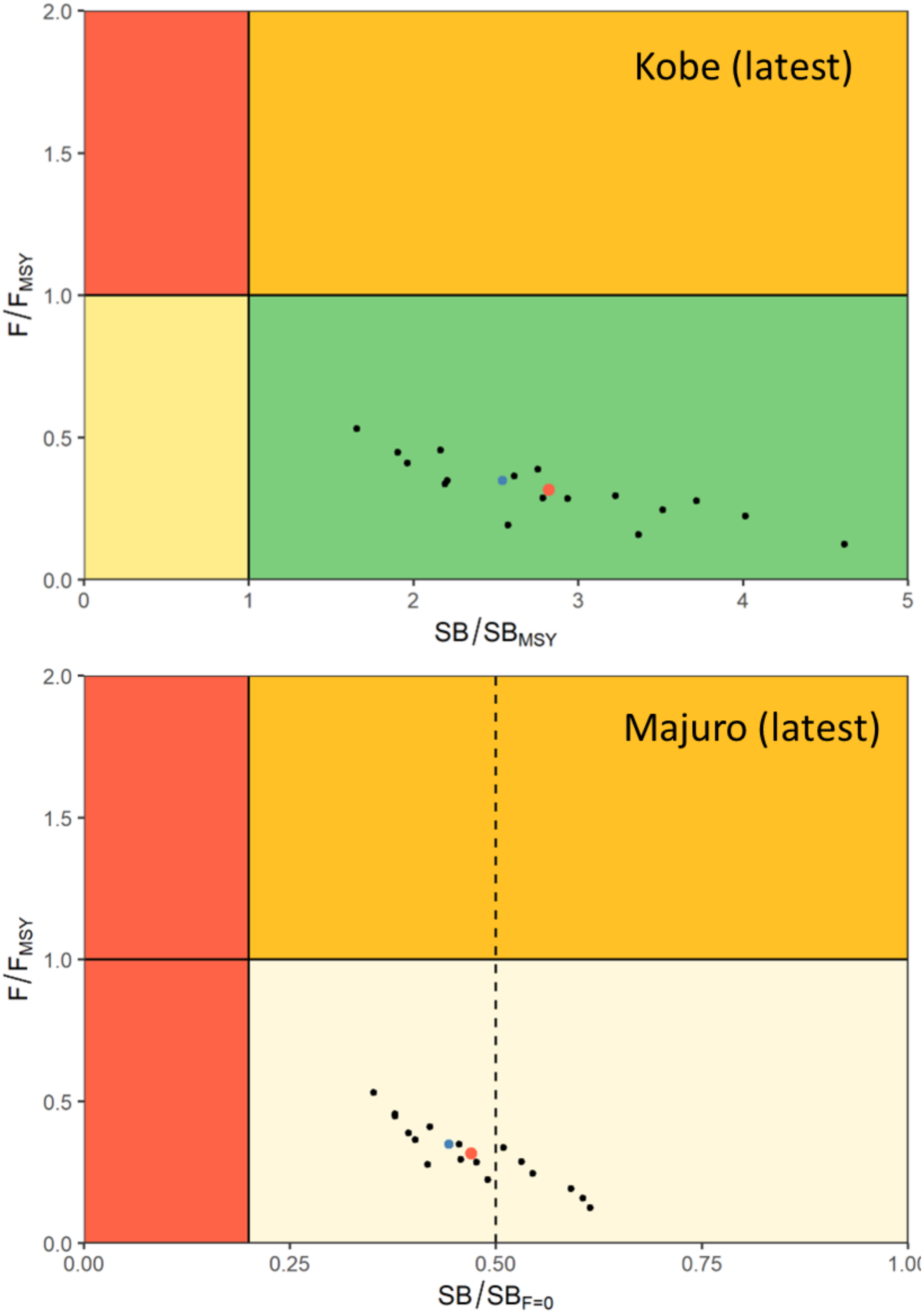


Figure SKJ-11. Kobe (top) and Majuro (bottom) plots summarising the results for each of the models in the structural uncertainty grid for the ‘latest’ (2021) period. The vertical dotted line on the Majuro plot is included to indicate the interim TRP of $0.50SB_{F=0}$ for the WCPFC-CA skipjack stock as specified in CMM 2021-01. The blue point is the diagnostic model, and the red point is the median.

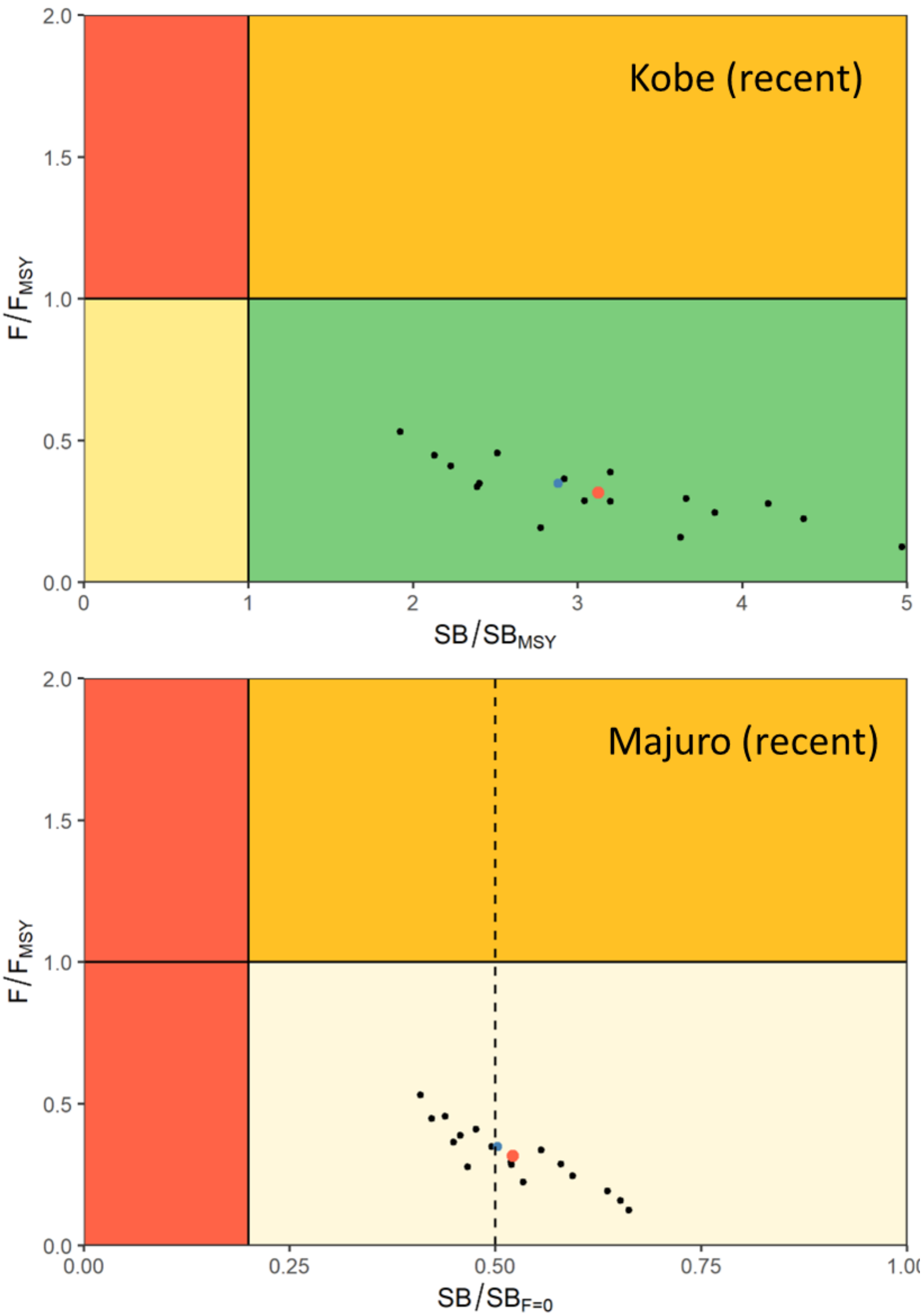


Figure SKJ-12. Kobe (top) and Majuro (bottom) plots summarising the results for each of the models in the structural uncertainty grid for the ‘recent’ (2018-2021) period. The vertical dotted line on the Majuro plot is included to indicate the interim TRP of $0.50SB_{F=0}$ for the WCPFC-CA skipjack stock as specified in CMM 2021-01. The blue point is the diagnostic model, and the red point is the median.

9. SC18 noted that the skipjack assessment continues to show that the stock is currently moderately exploited and the level of fishing mortality is sustainable.

10. SC18 noted that the stock was assessed to be above the adopted LRP and fished at rates below F_{MSY} with 100% probability. Therefore, the skipjack stock is not overfished, nor subject to overfishing. At the same time, it was also noted that fishing mortality is continuously increasing for both adult and juvenile stages while the estimated spawning potential has shown a declining trend since the mid to late 2000s, and spawning potential depletion reached a historically low level in recent years.

11. SC18 noted that levels of fishing mortality and depletion differ between regions, and that fishery impact was highest in the tropical region (Regions 5, 6, 7 and 8 in the stock assessment model), mainly due to the purse seine fisheries in the equatorial Pacific and the "other" fisheries within the Western Pacific.

b. *Management advice and implications*

(i) Management advice specific to skipjack

12. SC18 did not achieve a consensus on the management advice for skipjack tuna in the WCPO.

(ii) General recommendations for WCPFC stock assessments

13. SC18 noted the challenge of fully reviewing the key inputs into WCPFC stock assessments and providing feedback within the time available. SC recommended that approaches that may address this issue be discussed at SC19 and recommended that the Scientific Services Provider develop a discussion paper to inform those discussions.

Model diagnostics

14. Model diagnostics serve an important function in the stock assessment process. They are integral to the development of a sensible assessment model, and are critical for reviewers to assess whether proposed models are suitable for the provision of management advice. This is especially true at the SC where reviewers have a short period of time to review assessments and obtain clarification from the Scientific Services Provider about areas of concern.

15. Key diagnostics are required for both the diagnostic case model and for models included in the structural uncertainty grid. In the case of 2022 WCPO skipjack SC18 thanked the assessment authors for updating the assessment report to include these diagnostics and note that the Shiny app[4] is a useful tool. However, SC18 also noted a lack of consistency in the level of available diagnostics between assessments of different species. In light of this, SC18 recommended that SC19 consider guidelines for WCPFC stock assessments defining:

- The minimum set of diagnostics that should be provided for each model being considered for management advice;
- Consideration of the importance and interpretation of alternative model diagnostics depending on how the assessment is used to provide management advice (i.e., single best model vs. ensembles and structural uncertainty grids);
- For key input analyses, such as the preparation of standardized indices of abundance, the minimum set of diagnostics that should be included in the supporting working paper or information paper describing the analysis; and

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[4] R Shiny app for exploring the diagnostics and outputs from the 2022 WCPO skipjack stock assessment is available at: https://ofp-sam.shinyapps.io/GridSKJ2022/

- Guidelines for the graphical presentation of diagnostics to ensure legibility.

(iii) Research recommendations specific to the WCPO skipjack assessment

16. SC18 identified a wide range of cross-cutting research recommendations for inclusion within the WCPFC tuna research plan for consideration, prioritisation and sequencing at SC19. SC18 noted the research recommendations made in SC18-SA-WP-01 (*Stock assessment of skipjack tuna in the western and central Pacific Ocean: 2022*) and suggested the following items for consideration as high-priority research areas:

- Hyperstability and effort creep in the CPUE indices, and incorporation of CPUE uncertainty in assessment results (i.e. inclusion as an axis in the structural uncertainty grid), including alternative model assumptions related to regional scaling
- Data conflicts that affect assessment outcomes, and approaches to resolving them.
- Review the model specification with the goal of conforming to the set of diagnostic criteria to determine whether an assessment model is suitable to provide management advice.
- Assumptions dealing with the parametrization of key model settings, such as the fishing effort regression used in the catch-conditioned approach to minimize their impact on estimates of stock status
- Tag mixing, including estimation using observed data, simulation, and simulation validation.

17. SC18 noted the terms of reference (TOR) for Project 18X2a and 18X2b (*Further development of ensemble model approaches for presenting stock assessment uncertainty*) and Project 18X4 (*Exploring evidence and mechanisms for a long-term increasing trend in recruitment of skipjack tuna in the equatorial Pacific and the development and modelling of defensible effort creep scenarios*) in SC18-GN-IP-07[5], which would address further issues of importance.

18. SC18 noted additional items that had relevance for both skipjack and wider WCPFC tuna stock assessments considered by the SC and ISC. These and additional items to consider where possible are further detailed below. Items also relevant to the upcoming WCPO yellowfin tuna peer review are denoted with an asterisk (*).

i) Indices of abundance: *
   - Investigate a range of hypotheses which encompass the uncertainties in the spatial-temporal dynamics of the stock and the fishing effort.
   - Refine effort creep scenarios for the Japanese pole-and-line fishery and equatorial purse seine fisheries.
   - Develop alternative approaches for the interpolation of abundance into unfished areas when spatially averaging predictions to compute regional scalers. The use of preferential sampling models for standardizing CPUE data should be considered.
   - Consider the biological limits to the spatiotemporal distribution of skipjack when making predictions of biomass in unfished areas with spatiotemporal models.
   - Conduct analyses to incorporate additional process error in CPUE indices
   - Evaluation of alternative sources of CPUE time series, such as FAD echo sounder buoys or additional indices for the purse seine fishery.

ii) Data conflicts *
   - Likelihood profiles show conflict between data sources included in the model. The cause of these conflicts should be identified and methods to address them should be explored.

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[5] https://meetings.wcpfc.int/node/16222

iii) Trend in estimated recruitment:

- Estimated WCPO skipjack recruitment steadily increased between 1975 and 2010. Possible explanations for this trend should be researched, including model misspecification. If the trend is related to model misspecification options to resolve it within the model should be presented, The SC noted the TOR for Project 18X4 (*Exploring evidence and mechanisms for a long-term increasing trend in recruitment of skipjack tuna in the equatorial Pacific and the development and modelling of defensible effort creep scenarios*) in SC18-GN-IP-07.

iv) Recruitment distribution by region and season

- Consider the thermal limits to the spatiotemporal distribution of skipjack recruitment within the model settings.

v) Growth *

- Model diagnostics for each growth curve indicate poor fit to some components of the size data. Given the potential for spatial and temporal growth variation which any assessment cannot represent, recommend approaches to modeling growth and fitting size data that are robust to the potential for bias due to systematic lack of fit.
- Support epigenetic aging for skipjack in the long-term while work progressing age validation and age estimation using otolith and spines should still be pursued.

vi) Tag mixing *

- Examine the utility of alternative approaches for including tagging data in the assessment, such as estimating movement and harvest rate parameters outside the assessment model and including them as priors.
- Review evidence for rates of tag mixing based on the tagging data included in the stock assessment.
- Consider the role of the Ikamoana simulation model in exploring scenarios of tag mixing, and the need for validation by comparing simulated and observed tag recovery patterns.

vii) Tag reporting rates *

- Identify approaches to prevent tag reporting rates being estimated on the boundary, as these indicate some form of model misspecification such as incomplete tag mixing or data conflicts.

viii) Model structure enabling a converged solution *

- Review the model structure as it relates to achieving a converged solution. This includes consideration of the spatial structure as well as confirming that estimated parameters are identifiable and well-determined. Consider the utility of such models for the provision of management advice, including evaluation of relevant CMMs.

ix) Specification of the catch-conditioned model *

- Estimation of the required fishing mortality spline regression parameters attracted a large penalty in the likelihood and modified population scale. The impact of parameterization on estimated quantities should be examined.

x) Dirichlet-Multinomial set-up *

- Review grouping assumptions when setting up the Dirichlet-Multinomial likelihood for size composition data, and identify if the model is sensitive to grouping assumptions.

19. SC18 recommended that SC19 consider the need for a review of the skipjack tuna stock assessment taking into account the outcomes of the 2023 yellowfin review.